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THE GOLGI APPARATUS AND THE VACUOME IN PROTOZOA—SOME MISCONCEPTIONS AND THE QUESTION OF TERMINOLOGY.

(A Review)

By M K Subramaniam, M A , D Sc
AND
R Gopala Aiyar, M A , M Sc

(From the University Zoological Research Laboratory, Madras)

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Introduction

In a previous communication (Subramaniam, 1937), some of the criticisms offered by some of the cytologists against the existence of the Golgi apparatus in the cell have been discussed and it was shown that these criticisms, if accepted, would render critical, histological and cytological studies impossible It was pointed out that the reasons for denying the existence of the Golgi apparatus were —(1) Some cytologists were paying more attention to the technique allowing its morphology, position in the cell, size, constitution and function to fade into the background, (2) a tendency to consider the apparatus more as a substance than as a living inclusion, and (3) the introduction of personal bias resulting in a mistaken—though unintentional—interpretation of the results of other workers Nowhere is this more true than in the study of the Golgi apparatus in Protozoa This state of affairs has reached such a stage that we feel a clearing of some of the issues may be highly useful Hence, in this communication, we shall deal with some of the anomalies in interpretation of results and also the contention of some that the vacuome and Golgi apparatus are one and the same in Protozoa While we were going through the literature on Protozoa, Patten and Beams' (1936) paper on the use of the ultra-centrifuge on some living flagellates appeared These authors came to the conclusion that the identity of Golgi material in Euglenoid flagellates is still uncertain We were not at all surprised at this statement in view of the enormous confusion in the field

Instances of Confusion

Bowen (1926 *b*) in his review of the Golgi apparatus, comes to the conclusion from an analysis of various observations, that there is no *de novo* origin of the Golgi apparatus At the same time Gatenby and Nath (1926) arrived at an identical conclusion However, they consider that the phylogenetic origin of the Golgi apparatus, whether from the nucleus or from the cytoplasm, a different problem Thus a *de novo* origin of the Golgi being not accepted by leading cytologists, we were surprised to read Bowen's (1928 *d*) statement that a logical review of the methods for demonstration of the Golgi apparatus in various kinds of Protozoa is rendered impossible by the fact that no basis for the identification of what may or may not be the Golgi apparatus has yet been agreed upon According to Bowen in sporozoa alone is there any agreement If the Golgi apparatus does not arise *de novo*, the Golgi apparatus of metazoa should have evolved from that of Protozoa If there is agreement as to what is the Golgi apparatus in any one group of Protozoa, say the sporozoa, the fact will be admitted that confusion in other groups should be more due to other causes than due to technique, unless cytoplasmic behaviour in sporozoa and other Protozoa can be said to be different

The suggestion made in some quarters (King and Gatenby, 1923) that the terminal bead of the flagellum of some primitive flagellate represents the Golgi apparatus has not contributed to a clearing of the position Gatenby supposes that the outer layer of the bead might have been differentiated to form a lipoid store-house or elaborator of energy yielding materials necessary for the nutrition of the locomotor organ From its primitive position in the metazoan cell, always associated at some time with the centrosome-centrosphere complex, Gatenby believes that in the early history of the cell the Golgi apparatus and the centrosome were evolved side by side or the apparatus from the centrosphere in some way This speculation which is given undue prominence in the review of King (1927) probably led to the doubt expressed by Bowen Even after Hirschler's (1927) and Brown's (1930) demonstration of the Golgi in Sarcodina, Hill in her review (1933) says that the parabasal hypothesis was supported by much practical evidence put forward by Duboscq and Grasse (1924, 1925 *a*, 1925 *b*, 1927, 1928) The theory was based on the suppositions (1) that the chromophobic part of the Golgi bodies is related to the sphere in some way and that the relation between the central apparatus and the Golgi is not merely topographical, (2) that the flagellates were the most primitive Protozoans, and (3) that the Golgi apparatus originated in primitive flagellate-like Protozoa The fact that workers in Protozoa have tried to prove the existence of the Golgi apparatus shows that everybody feels that such a structure should occur in all Protozoa Instead of trying to prove or disprove the theory of Gatenby, Protozoologists seem to have been searching for the material composing the apparatus than the actual structure which is a living inclusion That this is the case will be seen from Hall's (1930 *a*) criticism that since little is known about the Golgi in Protozoa, the Golgi material lacks the venerable antiquity necessary to the foundation of any concept of a 'classical' Golgi apparatus in Protozoa

Criteria for the Golgi and its Non-Application by Workers

King and Gatenby (1923) gave the following criteria according to which they consider certain bodies seen in the cytoplasm of a coccidian to be the Golgi apparatus (1) Its staining and fixing reactions are identical with those of the Golgi bodies of metazoa (2) It occupies an excentric, juxtanuclear position and spreads out in the cell cytoplasm as does the Golgi apparatus in many metazoan cells, *e g*, the egg and the nerve cell (3) It consists mostly of the very characteristically shaped crescents and beads known in the case of metazoan cell as dictyosomes (4) As in the metazoan cell, these protozoan dictyosomes can be found dividing among themselves in the ground cytoplasm (5) During division of the cell it becomes sorted out into sub-equal groups around each nucleus and each ultimate daughter nucleus has gathered near it a part of the original apparatus This definition is not given due importance in the reviews of King (1927) and Hill (1933) and it is clear that application of the above criteria would rule out the suggestion that the parabasal bodies, the contractile vacuole and the stigma can by themselves constitute the Golgi apparatus Thus having lost sight of criteria that define the Golgi apparatus each Protozoologist seems to have his or her criteria as to what constitutes the Golgi apparatus Thus Brown (1930 *a*) defines the Golgi appratus as follows —(1) Consistent, not merely occasional, impregnation by osmic methods, (2) Resistance to the usual methods of bleaching after osmication, (3) Consistent impregnation by silver methods, (4) Occurrence in Protozoa generally and not merely in certain species, (5) General similarity of form in different Protozoa A comparison of the above criteria with those of King and Gatenby (1923) will show that some of the important ones have been left out The definition of Brown is also in essence that of Hall (1931) who considers that neutral red stains the Golgi apparatus and treats the Golgi apparatus in Protozoa as having peculiar staining reactions That this is the case will be seen from the following statement by Hall (1930 *a*) "On the other hand, it must be admitted that there are able cytologists who are not in accord with Bowen on this point, and who even go so far as to believe that the 'classical' Golgi apparatus may be a fusion product of discrete inclusions, either neutral red stainable globules (Covell and Scott, 1928, Cowdry and Scott, 1928), or in part of modified mitochondria (the 'lepidosomes of Parat)" If this is so, we have not been able to understand why Hall should be particular to call his neutral red staining globules Golgi apparatus and Golgi bodies Applying these criteria Hall describes certain inclusions in *Arcella* (Nigrelli and Hall, 1930) He says that these inclusions of *Arcella* are obviously more similar to the so-called ' vacuome' (Parat, 1928) than to the Golgi apparatus "Hence it would seem that, if vacuome and Golgi material are separate and distinct cell constituents, *Arcella* possesses only inclusions which apparently belong to the former category " Hall's conception of the vacuome is not apparently Parat's conception In *Peranema* (1929) Hall found certain neutral red staining globules and unstained vacuoles in the cytoplasm These neutral red staining bodies according to him resemble those in sporozoa (Joyet-Lavergne, 1926 , Cowdry and Scott, 1928) but differ from the vacuoles of *Euglena* (Grasse, 1925), *Ceratium* and *Peridinium* (Danegard, 1923) which are stained by neutral red and cresyl blue Hall rejects the idea of the vacuoles in *Peranema* being homologous to the vacuoles described by Grasse and Danegard because the staining was irregular, and only few vacuoles were stained in any one specimen , the staining was always very faint and furthermore these vacuoles showed irregularity of reaction to osmic impregnation which was not observed in the small globules Having thus shown the doubtful nature of the bodies we shall now show that his criticisms of other workers' observations appear to be not logical at all The Golgi apparatus has been shown by Hirschler to be vesicular and also semi-lunar in shape and these bodies were shown to have a duplex structure In none of Hall's papers is there any reference to any duplex structure Hall (1930 *a*, 1930 *b*, 1931) attempts to compare the ' osmiophilic globules ' of Protozoa seen by him with those of metazoa because of similarity in general form, intra-cellular distribution and blackening in osmic and silver impregnation The comparison is out of place because shape and structure described in metazoan Golgi as well as that described by Hirschler in *Endamœba* and gregarines (1927) are not certainly the globules of Hall Hall saw in *Chromulina* (1930 *a*) blackened crescents or almost complete rims of small vacuoles bordering a less densely impregnated substance He dismisses these appearances because Parat (1928) showed that incomplete fixation followed by osmic impregnation resulted in appearance of such ' crescents ' while longer periods of fixation produced only uniformly impregnated globules In Da Fano preparations of *Trichamœba* (1930 *b*) also, he found crescents and rings, but he dismisses these, following Parat, as artifacts as longer fixation produced homogeneously blackened globules Parat's observations and opinions are accepted by Hall and collaborators only to a certain extent Full acceptance would have meant acceptance of some of the bodies as modified mitochondria or lepidosomes This attempt at reconciliation between two schools of thought divided by a wide gulf becomes all the more difficult to understand when we consider some of the arguments put forward by Hall Bowen asserted that the Golgi apparatus in metazoa is not stained by neutral red Bowen in his review of Protozoa (1928 *d*) says "In gregarines (*Gregarina cuneata, G polymorpha* and *Steinina ovalis*) Joyet-Lavergne (1926 *b*) finds that after the slow action of a sufficiently dilute neutral red solution, small red arcs, strongly coloured, appear in the cytoplasm, each bordering an ovoid mass weakly coloured by neutral red These bodies correspond exactly with the morphology, size and location of Golgi bodies demonstrated by methods of fixation and staining, and are similarly interpreted " This sentence is misquoted by Hall in support of his contention that neutral red stains Golgi bodies thus " Joyet-Lavergne (1926) finds that after the slow action of a sufficiently dilute neutral red solution, small red arcs (and also granules), strongly coloured, appear " The important point of the arcs bordering the ovoid mass being omitted gives a very different meaning to the quotation from Bowen If small red arcs appear in the cytoplasm there is no reason to accept Parat's suggestion that the crescent-shaped bodies are artifacts On the other hand, if they are artifacts, Hall (1931) should not have used Joyet-Lavergne's (1926) evidence of the arcs staining with neutral red and blackening with osmic acid and silver nitrate, to argue against Beams and Goldsmith (1930), who said that bodies stained by neutral red and subsequently impregnated with osmic acid may be due to the direct chemical action between osmic acid and neutral red, instead of the action of osmic acid upon pre-formed contents of the vacuole Hall's answer is that Joyet-Lavergne described osmiophilic inclusions in a number of Protozoa based on material impregnated by the usual methods without previous treatment with vital dyes " In a later investigation, Joyet-Lavergne (1926) stained certain gregarines vitally with neutral red and was so impressed with the similarity between the neutral red globules and the previously demonstrated osmiophilic globules that he concluded the two sets of inclusions must be identical " We have not been able to reconcile the observation of Joyet-Lavergne in sporozoa of " small red arcs strongly coloured—each bordering an ovoid mass weakly stained with neutral red " with Hall's statement of " neutral red globules and osmiophilic globules"

Having shown thus far that the attitude taken by Hall is a mistaken one, we shall now show that Hall's papers do not give an idea of the ' vacuome ' or Golgi being considered as living inclusions When terming any set of inclusions, Golgi apparatus or vacuome, Hall should have realised that the cytologists dealing with these inclusions have been considering them as living inclusions Gatenby even in 1919 has shown that the Golgi have the power to assimilate, grow and divide Even 'vacuome' "appear never to arise *de novo* (?) but are permanent elements of the cell handed on in cell division and in reproduction and are presumed to have a status comparable to that of the nucleus, plastidome and cytome" (Bowen, 1927) That being so, during cell division these 'globules' should divide equally between the daughter cells and as the number thus becomes reduced they should exhibit vegetative division during cell growth In the whole series of papers Hall refers to fluctutions in numbers only in *Vorticella* (Hall and Dunihue, 1930) and *Chlamydomonas* (Hall and Nigrelli, 1931) Even here he does not deal with these fluctuations as caused by division as the following observations of his would show In different specimens of *Vorticella*, he says, the number and to some extent, the size of the neutral red globules vary Ciliates from one culture may show very few globules as compared with specimens from another culture In one instance, specimens from a three-day culture containing many dividing forms, showed very few globules as compared with material from older cultures After a week or more however, this difference was not noticeable "It seems that there is little accumulation of neutral red globules in *Vorticella* during the first few days after a culture is started, and it is not until the ciliates begin to divide less rapidly that they contain many neutral red globules These observations might suggest that the vacuome bears some relation to the storage of food materials or the accumulation of waste products in the cytoplasm " In *Chlamydomonas* (Hall and Nigrelli, 1931), the larger flagellates usually contain more globules than the smaller ones and the larger the globules, the fewer they are in any one specimen The appearance of large globules according to Hall, cannot be due to conditions encountered in sealed slide preparations since such variations were seen in flagellates from fresh stock cultures " These variations suggest the possible occurrence of fusion or growth of smaller globules and breaking up of larger ones " Thus Hall and collaborators have no clear cut ideas of the division of Golgi bodies

In coming to a conclusion from the above analysis we feel that many of the Protozoan workers do not seem to have applied the criteria which define the Golgi apparatus in metazoa This indefiniteness about what constitutes the Golgi apparatus, and an acquaintance, in several cases, with papers on Protozoan cytology alone, have led to the mistaken belief that the vesicles and rings are artifacts The duplex structure of the Golgi bodies is not considered at all and hence any attempt to bring the observations of vital staining in Protozoa with those in metazoa is impossible because of the fact that no distinction into chromophilic and chromophobic portions have been distinguished by many of the workers who assert that neutral red stains Golgi bodies Joyet-Lavergne admits that the staining does not remain long in the elements This evidence of temporary staining of the Golgi bodies has been used to demonstrate the Golgi material and has led to the mistaken belief that in Protozoa at least the vacuome and the Golgi apparatus are one and the same thing Criticisms have been offered by many that these neutral red staining bodies are volutin, etc Leaving aside such criticisms we shall now consider whether the terms 'vacuome' and Golgi apparatus could be used for the same structure

According to Hall and Dunihue (1931) the usage of the terms 'vacuome' by some workers and 'Golgi apparatus' by some others for the neutral red globules seems to be merely a question of terminology rather than anything else, since neutral red globules apparently satisfy the essential requirements for either classification Such a statement raises some fundamental issues such as (1) what is the Golgi apparatus and (2) what is the vacuome? As the Golgi apparatus was first demonstrated in metazoan cells and as modern conceptions about shape, structure and function of the Golgi apparatus have been largely based on the studies of cells from both vertebrates and invertebrates, any structure if it has to be labelled the Golgi apparatus should show staining reactions and behaviour as noticed in metazoan cells unless it can be clearly proved that Golgi in Protozoa have a different structure, behaviour and function Hall and Dunihue after quoting Gatenby's (1929) statement that as the vacuome is not consistently argentophil the view that the vacuome is the Golgi apparatus is not tenable, remark that whether or not this objection of Gatenby is valid for metazoan cells, it fails to hold in Protozoa since a number of different workers have already shown that neutral red globules react consistently to silver as well as osmic impregnation Such a statement does not carry conviction and it is at best a very curious argument

In order to understand Hall's position we have to go back to his paper on "Osmiophilic Inclusions Similar to the Golgi Apparatus in the Flagellates *Chromulina*, *Chilomonas* and *Astasia*' (1930 *a*) There he mentions that Bowen himself had changed his opinion regarding the stainability of the Golgi material from 'certainly not' to 'probably not' and that other able cytologists go so far as to believe that the 'classical' Golgi apparatus may be a fusion product of either neutral red stainable globules or in part of modified mitochondria He continues that whatever may be the status of vital or supra vital staining in the demonstration of the metazoan Golgi apparatus there appears to be no such problem in Protozoa Bowen in his survey of the structure of the Golgi apparatus in metazoa (1926 *b*) came to the conclusion that "the important thing is that the Golgi apparatus is a substance, the exact modelling of which in the cell is purely a matter of secondary interest " In his " Introduction to the Methods for the Demonstration of the Golgi Apparatus Part I " (1928 *a* May) while speaking generally of the silver technique for the demonstration of the Golgi, he mentions that the lack of specificity in staining reaction will doubtless seem a very serious drawback, and that in inexperienced hands, sometimes in experienced ones, the dangers of misinterpretation are very real However, as in the case of silver methods in neurological studies, he feels that there is no reason to discount the real value of the technique Rather is it our problem he says, to seize upon the results which come to us and make the most of them, and that such by-products of efforts to demonstrate the Golgi apparatus have sometimes proved more valuable than would have been the result had a more specific stain been obtainable The moral of all this is that one should be careful and that the " criteria for identification of the Golgi apparatus in a given case must be based upon its morphology and behaviour, not upon its staining capacity "

In his paper on osmic impregnation (1928 *c*, July) he comes to the conclusion that " of all known methods for demonstrating Golgi material, that of osmic impregnation is by far the best " Hall confuses all these statements of Bowen and comes to the conclusion " This final decree leaves only ' morphology and behaviour ' as the fundamental criteria for identification of Golgi material " It will be seen from the chronological order in which Bowen's conclusions are given that the decree attributed by Hall to Bowen is not final at all, for it is in a later paper and not in the same that Bowen says that osmic acid is the best known substance for the demonstration of the Golgi material Thus Hall leaves out the staining with osmic acid and applying the criteria of ' morphology and behaviour ' comes to the conclusion that the criterion of behaviour fails to offer any parallel between sporozoa and metazoa According to him if one accepts the 'Golgi apparatus ' of sporozoa as homologous with that of the metazoa in spite of the scanty evidence offered by Bowen's single available criterion ' morphology ', then the logical deduction seems to be that any set of granular, globular, elongated or crescent-shaped inclusions in the Protozoa may be considered Golgi apparatus provided first, that they are blackened in osmic impregnation (and withstand the usual bleaching methods) and second that they may be distinguished from chondriosomes An additional criterion, that of vital staining with neutral red may, according to him, be used to identify the Golgi material of other Protozoa with that found in sporozoa Having shown previously that Bowen's stress upon ' morphology and behaviour ' did not weaken his assertion that osmic acid is the best known substance for the demonstration of the Golgi apparatus, we shall now show that 'morphology and behaviour' are as important According to Hall if one accepts the contention of Bowen that the staining capacity must not be relied upon, the only other criterion left is the resemblance in shape between the sporozoan Golgi elements and the discrete metazoan Golgi bodies which vary both in size and form The above statement cannot be accepted since King and Gatenby (1923) and Joyet-Lavergne (1924) compare the behaviour of the Golgi bodies in various sporozoa to the behaviour of the same cell organ in some eggs, sperms and nerve cells

In somatic or germ cells which are in a quiescent condition the Golgi bodies in metazoa generally occupy a place near the centriole and just before cell division they get scattered throughout the cell and also increase in number When the daughter cells separate they have been known to be equally divided between the two daughter cells It is this characteristic that has been used as one of the criteria by King and Gatenby (1923) to identify some bodies seen in *Adelea* as the Golgi apparatus Hall (1930 *a*) himself mentions that the Golgi apparatus exhibits certain types of behaviour in spermatogenesis, secretory cells, etc A critical analysis of these fundamental characteristics has been made by Gatenby even as early as 1920 which led him to classify the Golgi apparatus among living 'protoplasmic inclusions', as distinguished from 'deutoplasmic' or non-living inclusions Further Gatenby comes to the conclusion (1919) that a uniform distribution of the mitochondria and Golgi apparatus during cell division has something to do with the control of cell metabolism Growth and division of Golgi bodies have been observed during increase in size of the cell just prior to division and during intense cellular activity Bowen (1928 *d*) apparently seems to have included the characteristics which led the Golgi apparatus to be included as 'protoplasmic inclusions' under the terms 'morphology and behaviour' Another contention of Hall (1930 *a*) seems to be that the dispersed sporozoan Golgi apparatus is not even remotely similar in morphology to the original "apparato reticolaro interno" of Golgi and since little is known about this phase of Protozoan cytology the Golgi material lacks the venerable antiquity necessary to the foundation of any concept of a 'classical' Golgi apparatus in the Protozoa It should be pointed out here that even though Golgi and his pupils conceived of the Golgi apparatus as essentially network-like in shape, Weigl was the first to show that in invertebrates they had a scattered distribution Weigl's corrosive osmic fixation followed by post-osmication are being used to-day and many workers have succeeded in demonstrating the Golgi apparatus by Weigl's technique in secretory cells of both vertebrates and invertebrates where though they have different shapes, they have an identical function (see especially Bowen, 1926 *a*). When it is remembered that Golgi's original technique and that of Weigl show networks in vetrebrate somatic cells and discrete bodies in invertebrates and germ cells, when different somatic cells of vertebrates themselves show discrete bodies (lipoid or skin glands) and networks and when networks themselves break up into discrete bodies during cell division, the usage of the term Golgi apparatus seems to have been based on staining reactions, morphology and behaviour. Even in Protozoa Hall's statement that the Golgi material lacks antiquity seems to be unjustified.

Hirschler even in 1914 demonstrated in sporozoa bodies which showed identical structure and behaviour as those found in metazoan cells investigated by him and hence any work on Protozoa on the Golgi bodies should proceed on the fundamental criteria employed by Hirschler, in terming bodies seen by him in sporozoa as the Golgi apparatus.

Golgi's "apparato reticolaro interno" has been designated by his disciples and followers as the Golgi apparatus and this procedure is followed by other students of cytology according to priority of nomenclature. Proceeding on this basis any particular cell inclusion in Protozoa should be termed Golgi apparatus if it satisfies the conditions according to which a host of workers have styled a particular organ of the cell as the 'Golgi apparatus' in metazoa. Hall hints that these discrete inclusions mentioned by him in *Chromulina*, *Astasia* and *Chilomonas* (1930 *a*) may not be the Golgi bodies at all in the metazoan sense and that there is a probability of their being merely metabolic products which show the characteristics of Golgi material. "Until more is known about this aspect of Protozoan cytology, such a question cannot be settled one way or another. In the meantime, whether we accept the rather convincing arguments of Parat or follow the somewhat bewildering dictates of Bowen, there is no reason why these discrete inclusions of Protozoa may not be accepted as true Golgi material, since, so far as the present criteria for identification of metazoan Golgi apparatus extend, these inclusions of Protozoa satisfy all essential requirements." We have not been able to understand this particular attitude of Hall. It is surprising that after stating the point of view of Parat that the classical Golgi apparatus may in part be modified mitochondria Hall suggests the acceptance of the discrete bodies as 'true Golgi material'. As pointed out previously the fact that neutral red does not probably stain the Golgi material in metazoa itself shows that the discrete bodies shown by Hall do not satisfy all the essential requirements. We should like to mention here that temporary staining of the chromophobic portion of the Golgi vesicles in *Meretrix* eggs have been noticed by us (Subramaniam, 1937), but never could the results be compared with what has been observed by Hall in various

Protozoa Neutral red vacuoles in *Meretrix* arise as segregation products and its segregation by the Golgi apparatus is comparable to the secretion of fat, fatty yolk and yolk in eggs

Hall's (1931) reasons for considering the vacuome as the classical Golgi apparatus seem to be that (1) the vacuome is consistently blackened in osmic impregnation (2) it is resistent to bleaching after osmication, (3) it is consistently impregnated by silver methods, (4) so far as available observations indicate, form and intra-cellular distribution of the elements of the vacuome are in general similar throughout Protozoa, and (5) a vacuome has been demonstrated in representative species of the major groups of Protozoa

It is surprising that Bowen (1928 *d*), King (1927) and Hill (1933) who noted the disagreement as to what constitutes the Golgi apparatus in Protozoa have not defined the criteria on which are based the identification of Golgi material in metazoa Such a clear analysis of the criteria of staining, structure, shape and morphology of the Golgi apparatus in the metazoa together with what constitutes the vacuome will, we believe, go a long way in clearing the position for a study of what constitutes the Golgi material in Protozoa

Definition of the Golgi Apparatus

1 The Golgi apparatus is a permanent structural element in the cytoplasm universally present in all cells

2 In quiescent cells generally it has an excentric juxta-nuclear position

3 It possesses the power of independent growth and multiplication and is passed on from cell generation to cell generation by division processes which have been shown to be of special interest

4 The Golgi apparatus arises only from pre-existing Golgi and does not arise *de novo*

5 The apparatus assumes various forms and in invertebrates and germ cells generally it is constituted by discrete bodies having a duplex structure

6 The apparatus has a lipoidal basis and may also have a second constituent which is protein in character

7 The Golgi material in many cases is set off rather sharply from the cytoplasmic background and could sometimes be seen in fresh material under ordinary and even dark ground illumination

8 The apparatus is consistently impregnated by osmic and silver technique and is resistant to the usual methods of bleaching after osmication.

9 The apparatus shows an increase in size following an increase in volume of the cytoplasm or during active synthesis of visible granules from raw materials in eggs, sperms and secretory cells This hypertrophy is by an increase in number mainly in invertebrates and germ cells—also in vertebrate lipoidal cells—and by an increase in complexity and size in those cells where networks occur

Parat lays down the following Points for the guidance of Workers in the Identification of the Vacuome

1 There are present in all cells two and only two kinds of formed elements in the cytoplasm The elements in question are (1) the chondriome or the mitochondria, stainable with janus green and (2) the vacuome stainable with neutral red Thus janus green and neutral red (especially Krall's Microcolor) are considered specific in a narrow sense

2 The chondriome is a lipoidal phase and the vacuome a watery one

3 The Golgi material of animal cells as usually described does not exist The appearance of a Golgi apparatus results from the fact that within, around and between the vacuoles of a cell osmic acid or silver nitrate is reduced to form an entirely artificial structure which going now this way, now that, produces that illusion of a rambling network Thus the network produced has no fixity of shape

To summarise, the first essential characteristic of the vacuome is its specificity for neutral red and the second, its constancy The third is the nature of the vacuolar contents which are never lipoidal (see Parat and Bergeot, 1925) but always watery with a reaction ' franchement acide ' and probably made up in most cases of a solution of crystalloids.

Facts against Considering the Vacuome as the Golgi Apparatus

1 Vacuoles are not universally present in animal cells

2 There are two types of neutral red staining structures (*a*) artificial and (*b*) pre-existing Hence neutral red cannot be considered specific

3 Osmic acid does not cause deposits within animal cell vacuoles

4 Parat's explanation of the artificial nature of the Golgi apparatus as seen after silver and osmic technique does not cover the discrete bodies of invertebrates His interpretation that the rod-shaped bodies of ***Helix*** are modified mitochondria is based on staining with janus green and if this has to be admitted, there is also the fact that the vacuome may often be stained with janus green which strikes at the very root of his theory

5 Even in lipoid gland cells of different kinds, the Golgi material appears in various forms always characteristic for a given cell type As

Parat has based his hypothesis on the results obtained in plant cells it may be mentioned here that though the vacuoles in the pro-meristem cells blacken, they have not been observed to have the remotest resemblance to a Golgi network Moreover no precipitations have been observed between the vacuoles either in plant or gland cells

6 The demonstration of the osmiophilic platelets (Bowen, 1927) and their being considered as homologous to the animal Golgi apparatus have shaken the fundamental basis of Parat's theory

As would appear from the criteria defining the vacuome, staining with neutral red is the most important criterion If this is so one wonders why the food vacuoles in Protozoa should not be termed vacuome Bearing in mind Parat's postulate it would appear that the food vacuoles in specimens studied by Hall satisfy more of the conditions than the osmiophilic bodies, for (1) they are all stained by neutral red, (2) often osmic acid and silver nitrate are precipitated inside these vacuoles, and (3) their contents are not generally lipoidal!

A persual of the above fundamental though elementary facts will show that the terms vacuome and Golgi apparatus cannot be used for the same structure If a body is to be considered as the vacuome, it cannot be termed Golgi apparatus for it is not lipoidal and if a body is considered the Golgi apparatus it cannot be considered the vacuome for it is not an acidic solution of crystalloids

In addition to the above fundamental differences between the vacuome and the Golgi apparatus, the test of cell nomenclature is how it works when applied to different categories of cells Considering the Golgi apparatus and the vacuome as essentially the same leads to enormous confusion making it difficult to reach any point of agreement between the different schools of thought Use of terminology is a matter where there cannot be serious differences of opinion and an agreed terminology together with criteria defining what constitutes the Golgi apparatus will clear the field for a correct understanding of the shape, structure and function of the Golgi bodies in Protozoa

Analysing the results obtained in Protozoa according to the above criteria it seems to us that the contractile vacuole, stigma and parabasal bodies could not be considered as the Golgi apparatus because they possess no power of independent growth and vegetative multiplication In *Jœnia annectans* Duboscq and Grasse (1928) particularly emphasise the secretory activity of the parabasal during division They saw chromophile vesicles each composed of a cap of chromophile substance surrounding chromophobe material being expelled into the cytoplasm Chatton and Grasse (1929) observed in *Polykrikos schwartzi* osmiophile vesicles Three streamer-like parabasals have also been seen by them and they are inclined to think that the vesicles are the products of granules liberated by the parabasal reminiscent of the secretion of very similar structures by the parabasal in *Jœnia*

Proceeding on the criteria given above for the identification of the Golgi apparatus the osmiophile vesicles together with the parabasals constitute the Golgi apparatus in *Jœnia* for only such a concept enables even the parabasal to be considered as Golgi as postulated by Grasse It is surprising that osmiophilic vesicles described by these authors which have identical reactions as the parabasal itself in *Jœnia* are interpreted by them as secretion, whereas they have to be considered as Golgi bodies Hill (1933) in her review misinterprets Brown's observations on *Microjœnia* and suggests that the vesicles and batonettes described by Brown may be mere vesicles secreted by the parabasal She forgets that in metazoa no case of a Golgi body secreting another has ever been noticed Taking both together, the osmiophile vesicles and the parabasal, they are seen to satisfy most of the conditions laid down for the identification of Golgi material in *Jœnia* If this is accepted, formation of osmiophile vesicles is not by secretion but by fragmentation It is not quite necessary that all parabasals should react to Golgi technique—and thus be considered parts of the apparatus—for the parabasals alone cannot constitute the Golgi apparatus Similarly the contractile vacuole alone cannot be accepted as the Golgi apparatus, for as in the case of parabasals and stigma it also does not show growth and vegetative multiplication though it may divide during cell division Hall (1930 *a*) records some interesting results in flagellates In a random example of 100 flagellates, 39 had both the contractile vacuole and the *globules* (which according to him stain with neutral red and are considered as Golgi) were blackened, 15 in which the *globules*, contractile vacuole and other cytoplasmic vacuoles were blackened, 9 in which the *globules* and cytoplasmic vacuoles but not the contractile vacuole remained blackened, 25 in which only the globules remained blackened, 3 in which the *globules* and cytoplasmic vacuoles were bleached completely, while the contractile vacuole was only partly bleached, and 9 in which the *globules* and vacuoles were completely bleached

Hall comes to the conclusion that as the *globules* were blackened in 88 per cent they alone are the Golgi bodies The same result offers another interpretation If the *globules* are to be accepted as the Golgi bodies, it will be seen that in the largest number of cases (39 per cent) with no artifacts both the contractile vacuole and the *globules* were blackened which leads to the logical conclusion that both together should be considered as Golgi apparatus in the particular flagellates

On the whole from a critical reading of the available literature it appears that what is described in many cases as Golgi apparatus in Protozoa, excepting probably the sporozoa, does not answer to the definition of the Golgi apparatus and that further critical studies, bearing in mind that some of the Golgi elements may become modified as the contractile vacuole, parabasal or stigma in some species, may offer a new approach to the study of the Golgi apparatus in Protozoa

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CLIMATIC CONDITIONS IN SIND.

BY PROF. MANECK B PITHAWALLA, B A , B Sc , L C P , F G S ,
Research Certificate, University of London

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I *Introduction*

PARTS of India form some of the warmest regions of the earth In this tropical country, having a climate of great diversity and range, Sind is found to be the driest and hottest of all its provinces, the distribution of solar radiation playing a prominent part in it Aridity is its main characteristic, with Jacobabad (mean maximum temperature 113° F and mean humidity 41 per cent) as the hottest and driest place in India The tropic of Cancer passes a little below its southern boundary and so the solar heat is great, coupled with longer hours of sunshine in the hot season The climate is reminiscent of the Sahara type, and of that prevailing in hot and dry lowlands. It presents a great contrast with Assam at the other end of the country, as regards humidity—a contrast greater than that between Egypt and the British Isles It is rather cold in winter for the latitudes within which it falls (*viz.*, 23° 35′ and 28° 30′ N), parts of it being cooler than the Punjab, situated higher up and encompassed between latitudes 29°-31° N

The thermal equator (the line of the greatest mean heat of the globe) passes through Sind "It has long been known that what is termed, the thermal equator, does not follow the course of the equinoctial line, where, on the average of the year, the sun's action is most direct and intense, but in the longitude of India bends northwards, running up through Ceylon and the peninsula to beyond the tropic and *passing through Sind*, crosses thence to the Arabian peninsula "[1]

In the matter of rainfall, another important factor of climate, the region also suffers greatly It is said to be "between the two monsoons", known as the S W. and N E. It manages to miss the influence of the former, while the latter does not extend much beyond the Ganges basin The average rainfall in the valley is meagre and precarious. Contrast with this the region of Western Deccan, which receives almost the whole of its annual rainfall in summer and in abundance, and the N.W.F. Province with its main share of rains in winter The mountains on the west of Sind are not sufficiently high to catch the S W. monsoon currents in one part of the year or to prevent the cold blasts from the Iranian Plateau from entering the region, in the other (See Plate I)

Thus the chief features which affect the climate of Sind are :—

(1) The tropical zone in its southern half and the temperate zone in its northern one

(2) The position and direction of mountains, *e g*, the Himalayas which prevent the northern cold and induce the southern rains

(3) The Thar Desert Region in the neighbourhood

(4) Nearness or remoteness from the Arabian Sea

(5) Presence or absence of forests.

Within the region of Sind there are some marked climatic contrasts. There is an uneven distribution of rainfall from one end of it to another. Jacobabad has an average rainfall of 3 inches, while Nagar Parkar has 15 inches There is almost no rainfall in some parts of the desert area ordinarily, but in years of heavy downpour a whole season's rainfall is received at some places in Sind in a couple of days, it being as heavy as 3 inches per hour, *e g*, on 17th June 1912, when 7 inches of rainfall were recorded at Karachi.[1a] Places nearer the sea get somewhat better and regular rains. The diurnal and seasonal variations of temperature are also great in many parts of Sind The thermometer drops below the freezing point in winter with frequent cold spells and frost in North Sind, while heat waves with whirlwinds and dust storms are common in summer throughout the Province There are no great forests in Sind to render the rainfall more effective except in a few narrow strips along the river banks Dry land winds blow most of the year. " It is this persistence of land winds which explains the aridity of the Indus Valley, for the south-west direction, that prevails in the Valley itself, is merely that which is given to the current by the trend of the hills that bound it."[8] This dry wind system prevails over the greater part of the Province, except near the coast, where the influence of the monsoon winds is felt somewhat But the chief causes of this draught in Sind are the deficient relief of land and the very high temperatures and low humidities, jointly operating to reduce the chances of rain or even of cloud formation (Ref. Simpson's theory in Section IV) On the whole, the climate of Sind can be called a Desert climate—a cold dry winter, alternating with a hot summer, with very meagre and precarious rainfall

II. General Climatic Conditions of India Affecting Sind

A The Monsoons.

India is one of the monsoon lands of Asia The word 'Monsoon' is derived from the Arabic ***mausim***, season or seasonal wind, the wind direction being the chief factor in the practice of navigation of those days This wind depends upon the principle that it always blows from places which have greater barometric pressure to where it is less This wind pressure gradient in its turn, depends upon the rate of heating and cooling between land and sea

The very nature of the peninsular projection of India into the Indian Ocean helps this During the months of March, April and May the sun's rays fall almost perpendicularly on Northern India and the barometric pressure in this region is the lowest, while over the Indian Ocean and lower down, the air is comparatively cool and the pressure high A flow of air is consequently generated inland from the seas, and, crossing them for nearly 4,000 miles, it is charged with considerable moisture Also the hotter the air, the more moisture it carries in an invisible form But this current of air does not flow directly from south to north, due to the rotation of the earth, the air currents in the Northern Hemisphere circulate anti-clockwise, hence the S E trade winds On crossing the equator, they are caught in the circulation around the low pressure system existing over the N W corner of India and Sind, and move, over the region of the Arabian Sea on one side and the Bay of Bengal on the other, deflected as the S W monsoon, according to Ferrel's Law At the equator due to the rotation of the earth, the monsoon has acquired a high velocity of hundreds of miles per hour;

but as it goes up to higher latitudes it reaches the air currents which move slower and hence overtake them, deflecting itself eastwards

Over Sind, there is in summer a persistent depression with an oval isobar of only 29 inches round about Jacobabad, and an isotherm of about 100° F co-terminous with it There is, therefore, a difference of nearly an inch of barometric pressure between South India and this region, which at once becomes a theatre of great atmospheric depression, breeding thunderstorms and air disturbances In this respect the contribution of Sind to the whole country of India and its rainfall is really very great

On entering India, this moisture is precipitated as the air advances northwards over the country, because the general pressure distribution over Asia and the Indian Ocean forces it into this box or *cul-de-sac*, out of which it can only find a way by rising over the sides "[1]

Causes of Precipitation —But though, the chief cause of the rainy season is this pressure distribution over land and sea, actual precipitation of rain is due to several other circumstances The orographical structure of the whole country is mainly responsible for it At the very outset the Western Ghats obstruct the path of the monsoon Such an obstruction is beneficial, as the air currents are pushed upon a height of nearly 5,000 ft and the vapour is condensed Also, as the currents blow across the whole country, they find no openings in the north, north-west and north-east being blocked by the extra-peninsular mountain ranges of insurmountable heights They, therefore, must rise higher and higher This ascensional movement, thousands of feet above the sea-level, causes complete condensation and rainfall for the country

Branches of the S W Monsoon —It should be noted that these ascensional movements flow in two different directions (1) Those flowing over the Arabian Sea crossing the Ghats and penetrating the Narbada and Tapti Valleys called the Arabian Sea branch and (2) Those blowing from the Bay of Bengal along the Burmese Yomas and the Assam Hills called the Bay branch of the summer monsoon Further still, as the Bay current is checked by the Himalayan barrier, it bends westwards as the S E monsoon and passing up the Gangetic Valley, it reaches the eastern limits of the Punjab in a very weak state

Those parts of India, which do not lie within the paths and ranges of these two S W and S E monsoon currents, those which lie in the rain-shadow areas, and those, again, which have low or no mountain barriers, receive scanty rainfall in this season Thus Mahabaleshwar, 4,500 ft. on the windward side of the Western Ghats, receives an average rainfall of 300 inches, Poona and Bangalore on the leeward side of the Western Ghats receive only 25 and 10 inches respectively, while Peshawar in the extreme N W gets less than 15 inches and Jacobabad in Sind less than 5 inches Most of Sind lies outside the path of the S W monsoon and it has no high mountain barriers to catch it The other branch of the summer monsoon, *viz*, the Bay current, giving as much as 500 inches (average) to the Assam Hills (Cherra Punjee), does not reach parts of Sind and the Punjab, as the currents get weaker and weaker as they travel further westward thus Peshawar gets only 4½ inches and Sukkur 2 inches during the whole summer season Even the cyclones, developed in the Bay of Bengal during the monsoon period, do not usually travel as far as the Indus basin

This wet season lasts for about four months from June to September, at the end of which period the moisture is exhausted and the currents become greatly weakened As a rule three-fourths of the total annual rainfall in India is caused by this monsoon current

N E. Monsoon—By the end of September, the meteorological conditions in India are reversed The rays of the sun are also aslant in these months While the S W monsoon is still hanging over the country, particularly over Bengal, the air over the greater part of Central Asia becomes cold and an anticyclone, exceeding 31 inches and resting on Tartary, is developed North of this region, the barometric pressure slopes away to the Arctic Ocean and south of it, it falls away to the equator, thus causing the Central Asiatic anticyclone to be persistent for some time

On account of these changed conditions, the S W monsoon current, still flowing into the Bay of Bengal, cannot enter this high pressure region, but retreats and goes round the area of low pressure in South India, as what is called, the *retreating monsoon* This is also called N E monsoon "After September, the region of chief indraught gradually travels southwards, the moisture-laden winds from the Indian Ocean no longer penetrate so far in a northerly direction Accordingly, in October the pressure in the Bay of Bengal is in general the lowest in the area, lying off the Madras coast, and from this time onwards, rain occurs in the *Peninsula* chiefly in connection with a series of depressions or areas of low pressure, which form in the Bay of Bengal and strike the coast The rain-bearing winds at such times are north-easterly and hence the rains of the N E monsoon "[4] This current does not affect Sind It gets gradually exhausted in its passage westwards and there is a break in the rains for about a month or so, *viz*, October

Winter Rains in Northern India—By November-December the temperature at Jacobabad falls as low as 50° F and though the pressure gradient is also low, steady winds begin to flow from the N.W. These are mainly continental winds and therefore, dry But where they pass over portions of the seas, such as the Persian Gulf, they carry some moisture which is condensed and precipitated by the northern winds Thus we have snows on the Himalayas and winter rains in Northern India

It should be borne in mind that the belt of high pressure and the anticyclonic conditions in winter are not local but stretch over a wide area of varying physical features from the Mediterranean to Central Asia as far as N E China, corresponding to the belts of high latitudes in the Atlantic and the Pacific Oceans As a result of this, shallow or feeble storms pass successively across Central Asia and occasionally also over Northern India. Thus lighty clouded skies and occasional showers of rain are the predominant weather conditions in winter in the Indus basin

B Other External Causes

Apart from the regular monsoon currents, such cyclonic storms or disturbances as cross the whole region are a very important feature of the climate of Sind Dr B N Banerjee[6] has classified the meteorological conditions prevailing over the section of the Persian Gulf to Karachi, under two distinct types, the winter and the summer, western depressions and eastern depressions respectively These storms differ from the regular cyclones, which are winds of great destructive violence but not bearing much rain The cyclonic storms, though milder, are very extensive and bring about winter rains in Northern India The difference of barometric pressure or gradient too is very small, *e g*, about $\frac{1}{10}$ inch "Also they are more lasting than the cyclones, and at times bring torrential rains They travel over hills without any loss of energy unlike cyclones, which are dissipated by mountains " Thus floods are caused when a shallow low disturbance is superimposed on the general regional flow It has been noticed that the Makran Coast from Gvadar to Karachi is disturbed more by summer weather storms than by winter ones, while in the interior of Sind and the Punjab it is the western (winter) disturbances which count more

Winter Conditions · Western Depressions —From December to February, depressions originate as far as the Atlantic Ocean and the Mediterranean Sea and periodically pass through the region of high pressure or the anticyclone belt created in Central Asia in the cold season. Whenever they pass over masses of water, *e g*, the Persian Gulf, they carry moisture which is ultimately precipitated as rain elsewhere There are original or parent depressions, which are formed at the meeting place between the polar and the equatorial air, and depending upon this "juxta-position of two different air masses, having different characteristic properties, such as temperature and humidity " Then there are secondary depressions, which are formed generally " when the members of the family are moving over hilly regions or are nearing the end of their activity ", and which having been thus formed, behave like other western depressions These depressions generally move north-eastwards along a big front, " Older members dying out at one end and new ones appearing at the other ".[6]

The nature of such a western disturbance is three-fold, that is to say, there are three distinct weather conditions, following one another, as it moves onwards (1) The *warm front* stage, whereby an air mass warmer and more humid moves forward and there is a sudden change of wind direction with rise of temperature and cloudy air accompanied by squally weather with passing clouds and drizzles or fog (2) The *warm sector* stage, by which weather becomes settled down but with very high temperature and humidity It is the steamhouse of the depression. (3) The *cold front* stage, whereby a mass of cold air enters the area and there is a sharp change of wind direction with a rise of barometric pressure, reduced humidity and sharp convectional currents The result is squalls, thunderstorms, dust-storms and showers of rain

These western depressions generally occur several times during a winter month and depend for their intensity upon the degree of contrast existing between the two air masses, pointed out above

Only a portion of these cyclonic storms or disturbances affects the Indus basin and Sind On reaching Makran, they generally split themselves into three streams covering (1) Western Highlands, (2) The Punjab and Kashmir and (3) Sind The last stream is rather feeble and so gives quite a little rainfall in the region of our study On crossing the Kirthar Range the storms usually develop secondary depressions which also create disturbed weather in Sind

Summer Weather and Eastern Depressions—From June to August, the low pressure area extends from N.W India to Iran and Arabia and depressions arising in the Bay of Bengal or the Arabian Sea and moving across Central India pass through this low pressure region Like the western disturbances, these storms are also caused by the encounter of air masses of different weather conditions, *e g*, the S.W monsoon winds and the N.E winds from the Bay At some times they die out when resting over Central India, but at other times fresh depressions arise from them over Rajputana " At the meeting place of the fresh Arabian Sea monsoon air and the land air which is the old and modified air from the Bay."[7] Whenever, such a secondary depression travels westwards with fresh vigour, there is a chance for Sind to get rains " These eastern depressions, when they are over N W. India, induce an inflow of the Arabian Sea monsoon current, which, because of its moisture contents, maintains the activity of the depressions, whereby cloudy weather, storm winds and rainfall occur in Sind "[*]

Also, while moving further towards the west into the Arabian Sea off Makran, such depressions cause rough seas and squally weather over the Pasni-Karachi section

Transition Periods —Between these two distinct periods of winter and summer depressions, *i e*, between September and November and between March and May, which are called *transition periods*, the characteristics of both the depressions are noticed,—not extensive storms, but only *localised weather disturbances* without any regular sequence of phenomena Thus feeble or strong, local or wide-spread disturbances of weather are likely to occur in Sind throughout the year

Cold and Heat Waves —The passage of cold and heat waves through our province can be understood easily, as the foreign disturbances described above are their cause As they pass over Sind, the weather invariably becomes abnormal, *i e*, abnormally hot at one time and abnormally cool at another These waves are the distinct triple-weather conditions noticed above, in connection with the depressions and disturbances Such weather spells are frequent in the winter months, *e g*, about half a dozen in January They have a mass of warm air in their southern and eastern quadrants and cool air in their northern and western quadrants As soon as they approach a station, there is a rise in temperature which then drops to several degrees below normal, when the depression has passed away The weather remains abnormal, until another depression from the west approaches Side by side with these disturbances there is good rainfall or snowfall in the localities crossed by them At times they travel eastwards as far as Bengal, Burma and Assam and even beyond, if they are strong enough

One or two examples of such waves may be cited here In January, 1935, a western disturbance passed over the Gulf of Oman, the Punjab, the United and the Central Provinces causing snow or rainfall in all these areas The depression was followed by cold waves, which affected Makran and Sind, Nawabshah recording the lowest temperature, of 27° F, while at other stations in Sind the freezing point was passed

The following minimum temperatures were recorded at Manora and Drigh Road, though the disturbance did not directly affect the two localities —

January 1935	Manora	Drigh Road	Fall of Temperature
12th	55° F	51° F	10° F –12° F.
13th	48° F.	40° F	
14th	47° F	37° F	

Notice the great difference also between the temperatures of the two places, *viz*, as much as 10° F, though they are only 10 miles distant

There was another instance of a heat wave, followed by a sudden drop in the temperatures, recorded at Drigh Road, during the same winter season, *viz*, on the 12th Novenber 1934

Hour	11th Nov	12th Nov	Fall of T
9–15 A M	79° F	75° F.	4° F.
10 A.M	85° F	79° F	6° F
11 A M.	91° F	83° F.	8° F
12 A M	94° F	85° F	9° F
1 P M	96° F	86° F	10° F
2 P M	98° F	86° F	12° F
3–45 P.M	98° F.	86° F	12° F.

Similarly, spells of heat in summer months are also usual *e g*

May 1937	Manora		Drigh Road		Departure from the Normal
	Max T	Min. T	Max. T	Min T	
16th	89° F	80° F	91° F	80° F	+5° F –10° F.
17th	87° F.	79° F.	102° F	81° F	
18th	94·6° F.	80° F.	111° F	81° F	

Such instances can be easily multiplied, the weather conditions of places under the disturbance being invariably abnormal for instance, temperatures in the Nawabshah District are very uneven for places not very far from one another. The effects are definitely localised

C. Local Storms.

In addition to these storms, there are other local afternoon disturbances occurring in Sind. They are due to convectional currents and contrasts of weather such as high temperature, diurnal range of temperature and differences in humidity, which cause thunderstorms, duststorms and squally weather, whenever there is the transition stage between the two seasons, *e g*, (1) March to May and (2) September to November During these months India is not affected by storms from abroad and it becomes "an independent meteorological area". They occur in Sind and the Punjab, and the time is generally in the afternoon, when these convective movements are the strongest At times, when the influence of a passing western disturbance from the Persian Gulf synchronises with the maximum convectional conditions of the afternoon, sharp thunderstorms and squalls may occur at a station but a neighbouring station may not be affected at all* The results are *local* dew, fog, rain, etc, while the general weather both at sea and upper air layers is more or less settled

Flood Years and Flood Menace—Due to such meteorological and other conditions, Sind gets abnormal floods in some years The following are some of the notable flood years in Sind

Before 1900	Since 1900
1841	1902
1858	1910
1874	1913
1882	1916
1892	1921
1895	1926
	1929

These floods are caused by two chief agencies.—

1. *Meteorological causes, as stated above*

2 *Physical features and conditions of drainage*—There are a number of Nais or hill-torrents from the western highlands bringing in torrents of water down into the valley below, *e g*, The Gaj, the Nari Often they flood the Larkana and Dadu Districts

On the other hand, the annual inundations of the Indus, which flows on a bed higher in level than the surrounding country, cause floods, which prove to be disastrous

3 *Artificial bund breaches*—Due to heavy floods and the force of torrents not only from the Nais but also of the Indus, breaches are made in the various

protective bunds, causing considerable damage to the fields and human beings. Such breaches are now controlled by the Public Works Department.

4 *Conditions in the upper reaches of the Indus* —These are the breaking of glacier dams, *e g* , Shyok glacier dam, snow-melting and river-damming by landslips.

III Climatic Divisions of Sind . the Seasons

The ancient writers divided this province of the Lower Indus Basin into three parallel zones, *viz* , Siro (Upper), Vachelo (Middle) and Lar (Lower) Sind, and from the point of view of climate they are found appropriate, though one is tempted at present to retain only the two chief ones, the Upper and the Lower [See Plate I(*a*)]

That these divisions are suitable for practical purposes can be seen from the following data [Average of 30 years (1901–1930) *India Weather Reviews*—India Meteorological Department]

Condition	Siro	Vachelo	Lar
Mean Max. Monthly T. (June 1919) ..	**117·4° F**	**110·8° F (1905)**	**96 8° F (1901)**
Mean Min. Monthly T. (Jan. 1903) ..	**38·2° F.**	**47·3° F (1925)**	**52·2° F. (1903)**
Range of T. (Seasonal) ..	**69° F**	**46° F**	**34° F**
(Monthly—May) ..	**49° F.**	**26° F**	**10° F**
Mean Humidity (Annual) ..	**57%**	**61%**	**73%**
Mean Rainfall (Annual) ..	**3·44″**	**7·92″**	**7·51″**

Characteristics of the Climatic Sub-Divisions.

1. *Upper Sind* —Chief locality . Jacobabad ; height above sea : 186 ft. ; distance from the sea . 300 miles

The dry atmosphere of the neighbouring highlands as well as the orographical features of the North West Frontier affect this region ; rainfall is the lowest in Sind and temperature is the highest (*e g*, the highest temperature recorded recently is 127° F in June 1919) The air is generally very dry There is a great range of temperature in winter and frost is common The climate resembles the continental

2 *Middle Sind*—Chief locality Hyderabad; height above sea: 96 ft., distance from the sea · 125 miles

The S W. monsoon winds have in this region an average speed of 11 miles per hour in June Rainfall is slightly more than at Karachi in some years The temperatures are lower here than in Upper Sind and humidity is moderate The range of temperature is also much less than that at Jacobabad Dry hot days and cool nights are summer characteristics of this sub-division

3 *Lower Sind*—Chief locality Karachi, height above sea 6 feet, distance from the sea 5 miles

The winding coastline affects this region to some extent This coastal and deltaic area is naturally damper, with smaller ranges of temperature and pressure The S W winds in summer and N E winds in winter are the prevailing air currents Rainfall is at times a little less than in Middle Sind Humidity is the greatest and the temperature moderate throughout the year Dampness causes muggy or oppressive weather in summer The climate is maritime

Seasons—In an arid sub-tropical region such as this, there are only three main seasons of nearly 4 months each

1 S W monsoon season, from July to October (the retreating monsoon does not affect it appreciably)
2 Cold season from November to February
3 Dry hot season from March to June

In (1), the rains are not general as in Peninsular India, but only occasional, the wind direction is S W or S E and humidity is on the increase The 15 days monsoon period is 9th July to 23rd July

In (2), the rains are only cyclonic storms and the usual direction of the wind is N or N E (Trade wind) When it does not rain and the sun shines, the weather is fine and bracing It gets cooler and cooler as we go from south to north from an average of 60° F at Karachi to 40° F at Jacobabad This is the touring season of India

In (3), the temperature of the air gradually rises to the maximum in June–July The sun shines directly over Sind and the wind direction changes from N W. to S E. The isotherm of 85° F. passes through Karachi, while round about Jacobabad the mean temperature is 95° F.

IV *Chief Climatic Factors and Elements*

It is now necessary to consider the chief climatic data that are available, *viz.*, temperature, barometric pressure, relative humidity, wind system and rainfall.

1 *Temperature*

Sind is uniformly very hot in summer and comparatively cool in winter, as the records of 30 years (1901–1930) clearly show (See Plate II)

Sind derives its heat from the following sources —

(i) The sun, which shines for the greater part of the year in cloudless skies

(ii) The rocks which are barren and the soil which is arid, sandy and saltish and which absorbs and radiates heat quickly

(iii) The warm front of the wave of a cyclonic storm approaching Sind

(iv) The warm N W winds from the Iran Plateau in summer

At times, there blows a harmful wind analogous to the Simoon of Arabia and the Sahara, while dust-storms with whirlwinds are common in the hot weather period The eddies, as much as 10 ft wide in dusty areas, rise to a height of some 200 ft

There are at the same time many ways in which heat is lost and cold ensues

(i) The air is still and the sky clear and there is little humidity or water vapour, in it to absorb heat

(ii) The rocks being barren and not covered with grass, there is quick radiation of heat towards the close of the day

(iii) Cold winds from the snow mountains in the north and the north-west blow during winter and reduce the temperature of Sind to a great extent

The month of January, for example, may be very cool from cold winds in one year and from nocturnal radiation of heat in another

Mean Maximum Temperature.—The graphs drawn, for the mean maximum temperature, show that there is a steady rise of temperature at Karachi, from 76° F in January to 91·6° F in June, which is the hottest month in the year It then begins to fall upto 86·7° F in August and remains more or less steady in September; then after a slight rise in October, it falls rapidly for November, December and January.

The graph for Hyderabad differs slightly from that for Karachi, in that the maximum temperature is reached in May, with a rapid fall up to

August In September and October there is a gentle rise and then a sudden fall again for the winter months of November, December and January.

Jacobabad is more irregular than either of the above stations. After the fall in winter there is a very steep ascent in February and March and a slight rise in April, then again a sudden rise for May till the maximum is reached in June The fall after June is also sudden and rapid with practically no rise in October, as in Middle and Lower Sind (See Plate II)

The average annual maximum temperature for Karachi is 85·5° F., for Hyderabad 93·3° F and for Jacobabad 95·5° F

Mean Maximum T.
Average of 30 years (1901–1930)
(*India Weather Reviews*)

Month	Karachi	Hyderabad	Jacobabad
January	76·0	75·8	72·7
February	77·7	81·4	77·5
March	83·1	92·5	90·7
April	87·0	101·2	101·8
May	90·2	107·0	111·3
June	91·6	104·6	113·7
July	89·6	99·6	108·5
August	86·7	95·5	103·9
September	86·8	96·7	102·9
October	88·5	97·5	98·8
November	86·1	88·9	87·3
December	79·2	78·2	75·5
Annual	85·5	93·3	95·5

Mean Minimum Temperature—The graphs of the mean minimum temperatures of the two stations of Karachi and Hyderabad are smoother than those for Jacobabad. The coldest month for all three places is January

The fall of temperature is greater at Jacobabad in September, and again in November and December than at the other two stations

The annual average minimum temperature at Karachi, comes to 71·2° F, at Hyderabad to 68·7° F and at Jacobabad to 66·4° F. only

Mean Minimum T

Average of 30 years (1901–1930)

(*India Weather Reviews*)

Month	Karachi	Hyderabad	Jacobabad
January	56·7	50·5	44·1
February	59·5	54·0	49·1
March	67·3	63·5	60·5
April	74·1	71·6	70·6
May	78·9	78·1	78·1
June	82·1	83·0	85·1
July	81·3	81·7	85·6
August	78·5	79·6	82·5
September	76·9	76·3	70·0
October	73·5	70·8	65·7
November	65·3	60·5	53·5
December	58·8	52·1	44·7
Annual	71·2	68·7	66·4

The above table shows that the coastal strip has a more equable climate than places further inland, Jacobabad faring the worst in this respect

Fluctuations in the Three Decades (1901–1930) —The graphs for the average temperatures (maximum and minimum) for the whole year indicate that they were more or less steady in all the decades for Hyderabad and Jacobabad, while those at Karachi slightly fluctuated. The following are the mean (mean of 30 years 1901–1930) temperatures at the three places :—

Station	Max T	Min T.	Average
Karachi	85·5° F	71·2° F.	78·3° F
Hyderabad	93·3° F.	68·7° F	81·0° F.
Jacobabad	95·5° F	66·4° F	80·9° F.

Range of Temperature.—Both as regards the daily and monthly ranges of temperature, Hyderabad and Jacobabad differ from Karachi, where the range is small, owing to the influence of the sea. But even at a little distance beyond the coast-line, *e.g.*, Drigh Road, it increases considerably.

The accompanying thermograms (see Plate II) of Karachi show the daily range near the sea very clearly. The daily range in summer months is much smaller than in November and December. The day's temperature is the highest in the afternoon, about 2 P.M., and the lowest in the early morning at 5 A.M.

At Drigh Road the daily range is upto 35° F., at Hyderabad upto 40° F and at Jacobabad upto 45° F.

The following table gives an indication of the monthly ranges of temperatures in Sind.

Mean Monthly Range of Temperatures

Month	Karachi	Hyderabad	Jacobabad
nuary	27·1° F	25·3° F	42·8° F
ay	10·8° F	26·5° F	49·5° F
ly	9·0° F	17·8° F	36·7° F.
ovember	5·7° F.	28·5° F.	50·4° F

(*Gazetteer of the Province of Sind* B Vols.)

The monthly range of temperature increases from the coast northwards till near the Upper Sind Frontier it goes to over 50° F in winter. It is also greater in winter than in summer. Owing to the S.W. monsoon current the range of temperature near the coast is not so great in summer.

2 *Barometric Pressure*

Indirectly due to these temperatures, the barometric pressure is the lowest at Jacobabad and the highest at Karachi The difference between the lowest pressure in July and the highest in December is (1) at Karachi, ·568 inches; (2) at Hyderabad, 621 inches and (3) at Jacobabad, 670 inches, as the following table of monthly average pressure shows —

Barometric Pressure

Average of 30 years (1901–1930)

(*India Weather Reviews*)

Month	Karachi	Hyderabad	Jacobabad	Remarks
January	30 090	30 006	29 921	
February	30 062	29 941	29 817	
March	29 938	29 834	29·733	
April	29 831	29 710	29 597	
May	29 723	29 589	29 160	
June	29 560	29 432	29·295	
July	29 522	29 391	29 260	Lowest in the year
August	29 599	29·467	29 353	
September	29 747	29 619	29 506	
October	29 902	29 796	29 699	
November	30 024	29 935	29 852	
December	30·090	30 012	29 930	Highest in the year.
Annual .	29 839	29 728	29 621	

3 *Relative Humidity*

There is a great divergence also in the relative humidity of the three stations The difference between Karachi and Jacobabad amounts to 35 per cent in the months of April and May The driest month in Karachi is December, whereas in Hyderabad and Jacobabad it is April due to there being more winter showers. The greatest amount of humidity, however, is in August at all three stations due to the influence of the S W. monsoon current Hyderabad is distinctly drier than Karachi, but Jacobabad is drier still

Average Monthly Humidity
Average of 30 years (1901-1930)
(*India Weather Reviews.*)

Month	Karachi %	Hyderabad %	Jacobabad %	Remarks
January	61	61	65	
February	67	58	54	
March	71	53	45	
April	76	52	41	Lowest in Upper and Middle Sind.
May	78	55	43	
June	79	64	57	
July	82	69	65	
August	81	72	71	Highest in all Sind.
September	82	70	68	
October	74	61	56	
November	62	55	56	
December	58	59	63	Lowest in Lower Sind.
Annual	73	61	57	

Thus in the interior the air is dry, though hot, in summer and hence not so distressing as on the coast; after sunset the humidity is reduced for a while, the heat from the ground radiating quickly, and nights are therefore cool As there is a greater range of temperature in winter, there is also a greater increase or decrease of humidity.

Frost—Some parts of Sind are visited by frost in winter, the necessary conditions being fulfilled, *viz*, *i.e*, (1) a clear sky, so that radiation is not hampered by clouds and (2) a calm night, when the layers of air in contact with the ground are cooled Whenever the temperature of the ground falls below the freezing point, the air in contact with it is so much cooled that the water vapour in its layers immediately above it or in the voids among the soils is condensed into ice particles or frost This kind of frost is found frequently in Upper Sind, but rarely in Lower Sind Some years are notable for severe and prolonged frost, causing great damage to crops, *e g*, 4th January to 4th February 1934[10]

Cloudiness —The skies in Sind are cloudy during the monsoon season and also during the months of December and January, but in other months they are very clear As a rule, afternoons are more cloudy than the rest of the day

4 *Wind System*

Average of 20 years (1901–1920)

(*India Weather Reviews*)

Season	Wind Direction	Karachi Days	Hyderabad Days	Jacobabad Days	Remarks
Cold Winter	N W	35	26	29	
	Calm	25	42	172	(Predominantly calm weather in Upper Sind)
	N	33	69	21	
	N.E	69	8	22	
Dry Hot	E.	16	2	24	
	S E.	4	5	62	
	S.	3	65	24	
Monsoon	S.W.	50	134	8	(Force of S W monsoon in Middle Sind)
	W	130	14	3	(Westerly wind predominant in Lower Sind)
Total No. of Days..		365	365	365	

The above data show that the predominant wind direction in Karachi is westerly for over four months of the year During the months of May to September, the general wind direction is S W and during the winter months of January, February, November and December it blows from the N E., while in the intermediate months, before and after the summer season, the direction changes to N W. It rarely blows from the south or east

At Hyderabad the S W direction is the most conspicuous from April to October, while in winter the N W. direction prevails

At Jacobabad there is practically no wind for half the year. During the other half the direction swings from S.E. to N.E. in the hot season and from N.E. to N.W. in winter. [See Plate I (*a*).]

The influence of the S.W. monsoon wind reaches nearly a hundred miles inland and so evenings are generally cool at Hyderabad in summer.

Wind Velocity (Miles per Hour)
Average of 20 years (1901–1920)
(*India Weather Reviews*)

Station	Jan.	Feb	Mar	Apl	May	June	July	Aug	Sept	Oct	Nov	Dec.	Annual
Karachi	6·4	7·4	9·2	11·4	13·1	14·6	14·9	13·7	10·7	7·6	5·9	6·2	10·3
Hyderabad	4·9	4·6	5·1	6·8	8·5	11·3	10·5	10·9	8·5	5·2	3·9	4·7	7·3
Jacobabad	1·7	2·3	3·1	3·5	3·7	4·4	4·7	3·8	3·3	1·8	1·3	1·3	2·9

The above table shows that near the seashore the wind velocity is greater, while in Upper Sind it is generally calm for nearly half the year. During the cold weather months the wind velocity varies from about 6 miles in Lower Sind to only about 1·5 miles in Upper Sind. It begins to increase from March and April, until it reaches its maximum velocity of about 15 miles in Lower Sind, about 11 miles in Middle Sind but only about 4–5 miles in Upper Sind. With the occurrence of dust storms and cyclonic rains, the wind velocity is naturally higher.

Local Land and Sea Breezes.—No special study of winds prevailing locally at the different centres has yet been made except at Karachi.[11] Recently owing to the requirements of the Drigh Road Airship Base and Aerodrome and as a result of the facilities available at the Meteorological Observatory there, Dr. Ramdas[11] has produced a valuable paper on the local afternoon sea breeze at Karachi, occurring during the non-monsoon period of October to March. This breeze is calculated to be a result of the difference in temperature and pressure above land and sea and due to the difference in solar insolation. His finding is that "The breeze sets in during the afternoon and has some of the characteristics of a cold front: it sets in suddenly, is usually colder, more moist and has a greater velocity than the preceding land breeze." This land breeze, again, is part of the prevailing winds at lower levels over the whole of Sind, the normal direction being N.W. and N.E. and the actual direction and strength of the winds are determined by the position and intensity of the seasonal anticyclone over North West India.

The general characteristics of the breeze have been summarised as under : "The sea-breeze first sets in at Manora, then moves towards Drigh Road through the Karachi City. The time taken by the sea breeze to reach the Airship Base varies from 1 to 3 hours. Before the arrival of the breeze at the Airship Base, the previous land breeze, if any, drops to calm and the setting in of sea breeze is accompanied by a fall of temperature (about 5° F to 3·5° F), rise of humidity (from 5% to 30% and above), shift of wind direction to west-south or south-west, and an increase of wind velocity. . The transition from land breeze to sea breeze is more and more marked as the latter proceeds inland. The sea breeze front appears to be somewhat diffuse near the coast but by the time it reaches the Airship Base it becomes quite sharp owing to increased contrast with the land-breeze."

It has been also noticed that this sea-breeze is not the actual gradiant wind, *i.e.*, westerly and north-westerly breeze but owing perhaps to the hills to the north-west and north of Karachi City, it is deflected largely to the west-south-west and south-west direction.

Thus it can be seen that in the climatic elements of temperature, barometric pressure, humidity and wind system, Sind in general has three distinct regions differing from one another. How far precipitation agrees with this analysis has to be seen now.

5. *Rainfall in the Lower Indus Basin*

Sind is called an "Unhappy Valley", perhaps on account of its scanty rainfall. "The Hindus of Sind," says R. F. Burton, "have a tradition that Hiranyakasipu, the demon king of Multan, was powerful enough to draw down Megha Raja, the cloud god from heaven and compel him to promise never to visit the valley of the Indus."

The orographic features of Sind lend support to such a belief. The average height of the surrounding hill ranges is only about 5,000 ft., while the Laki Hill lying in Kohistan just reaches a little above 2,000 ft. To catch the monsoon current a high mountain within the region is required. Again the alignment of the two ranges of mountains bordering the frontier of Sind, is not straight. There is a marked re-entrant angle in the north-west, which is very low. Any clouds that are caught by storms are again lost in them. Particularly in the case of Sind in winter, "the seat of maximum pressure is not the seat of maximum rainfall, nor indeed is the case of the great summer depression of Upper Sind and Lower Punjab of any precipitation whatever."[14]

But though the rainfall is meagre, it is a useful supplement to underground supply of water in many parts of Sind.

Annual Rainfall.—Being a portion of the *dry* monsoon belt, this region receives very little rainfall; it has very few rainy days, during the year, year after year, the average rainfall at any station, not amounting to 10 inches, as the following table shows:—

Rainfall Year by Year.

Average of 30 years (1901–1930)

(*India Weather Reviews*.)

Year	Karachi (Inches)	Rainy Days	Hyderabad (Inches)	Rainy Days	Jacobabad (Inches)	Rainy Days
1901	1·37		1·96		2·68	
1902	18·23		15·93		2·10	
1903	4 58		5 72		3·22	
1904	4 62		1·44		2·68	
1905	3·04		2 62		2·21	
1906	6·47		7 45		5·57	
1907	7 75		6·60		4·44	
1908	6·45		19 93		4·59	
1909	7 09		7·03		1·41	
1910	12·63		10 19		3·84	
1911	4·84		3 79		1·36	
1912	3 17		5·39		1 41	
1913	13·45		21·13		4·86	
1914	9·31		4 09		6·78	
1915	2·26		1·01		1 34	
1916	21·87		14 01		3·80	
1917	5·63		9 81		10·88	
1918	2·04		1·74		1·36	

Rainfall Year by Year—(Contd)

Year	Karachi (Inches)	Rainy Days	Hyderabad (Inches)	Rainy Days	Jacobabad (Inches)	Rainy Days
1919	3·39		7 76		3·23	
1920	1·97		1·70		2 26	
1921	16 90		13·78		3 58	
1922	1 99		2 66		0 13	
1923	5 57		5 21		4·73	
1924	3 69	9	12 07	10	2 11	5
1925	4·38	7	1·02	2	4 54	10
1926	20·04	11	12 11	13	4 28	10
1927	8 90	10	13 55	12	0 67	3
1928	2 39	5	2·14	5	0 90	3
1929	4 13	8	23 13	14	6 55	12
1930	16 70	12	2 77	6	5 67	4
Average ..	7 51	9	7 92	9	3·44	7

A special feature of the rainfall curves in Sind is that there are peaks of good rains and troughs of droughts at an interval of 5–6 years (See Plate III) It is remarkable that while there are a number of years of great scarcity of rainfall, there are years of abnormal rains and floods Also, these do not always coincide in all the three climatic divisions, *e g* , while 1926 was a flood year for Karachi, there was only 4·28 inches of rainfall at Jacobabad In 1929, Hyderabad received 23·13 inches but Karachi only 4 13 inches Nearer the coast, rainfall is greater than in Upper Sind, where the average is only 3·44 inches

Distribution of Rainfall—In the matter of distribution of rainfall in Sind, Nagar Parkar stands by itself Not only does it receive the advantage of its height but it touches, to some extent, the fringe of the S W monsoon current. Middle Sind receives slightly more rain than Lower Sind in some years while there is hardly any rain (less than 2 inches) in parts of Upper Sind Even in years of great floods there is not more than 10–12 inches of rainfall in this the driest part of the Province

Mean Annual Rainfall

(*India Weather Reviews*)

	Place	Mean Annual Rainfall	Rainy Days
	Nagar Parkar	14·85	17
Lower Sind	Tatta	8 83	8
	Karachi	7 51	9
Middle Sind	Umerkot	8 96	12
	Hyderabad	7 92	9
	Mirpurkhas*	9·55	9
	Nawabshah*	6 05	7
	Naoshero	4 26	6
	Sehvan	5·41	8
Upper Sind	Sukkur*	2 74	5
	Shikarpur	3·39	6
	Larkana*	3 55	5
	Jacobabad	3·44	7

Stations marked * have the averages taken for 17 years (1914–1930) The rest have those for 30 years (1901–1930).

At Sukkur the average rainfall is the least, *i e* , less than 3 inches, while at Nagar Parkar it is the heaviest, *i e* , nearly 15 inches At the intermediate stations it varies from about 5 inches to 10 inches. Also the average rain per day is a little less than 1 inch, the total number of rainy days amounting to 7 only (See Plate III)

Mean Monthly Rainfall —Though there are two distinct seasons of rainfall, *viz* , summer and winter, the following table shows that, on the whole, it is not only precarious and fitful, in both of them, but also scattered thinly throughout the year. The amount is, however, more in summer than in winter The actual monsoon period during the year is from 9th July (commencement) and 23rd July (withdrawal) (See Plate IV.)

Mean Monthly Rainfall

Average of 30 years (1901–1930)

(*India Weather Reviews*)

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
Nagar Parkar	0·03	0·15	0·09	0·01	0·27	0·64	6·18	4·52	2·49	0·39	0·04	0·04	14·85
Tatta	0·11	0·37	0·21	0·04	0·21	0·61	4·45	2·09	0·58	0·02	0·04	0·05	8·83
Karachi	0·31	0·46	0·34	0·07	0·10	0·57	2·76	1·85	0·78	0·03	0·10	0·15	7·51
Umerkot	0·09	0·14	0·17	0·01	0·17	0·36	3·79	2·72	1·34	0·13	0·01	0·03	8·96
Hyderabad	0·12	0·30	0·28	0·08	0·15	0·36	3·43	2·12	0·93	0·02	0·03	0·10	7·92
Mirpurkhas*	0·08	0·07	0·10	0·18	0·23	0·28	4·86	2·87	0·71	0·04	0·05	0·08	9·55
Nawabshah*	0·07	0·08	0·07	0·03	0·16	0·19	1·96	2·47	0·87	0·06	0·04	0·05	6·05
Naoshero	0·15	0·22	0·18	0·03	0·15	0·30	1·20	1·21	0·67	0·00	0·02	0·13	4·26
Sehvan	0·23	0·27	0·14	0·14	0·08	0·28	2·14	1·22	0·72	0·00	0·03	0·16	5·41
Sukkur*	0·04	0·15	0·14	0·03	0·17	0·06	0·86	0·90	0·18	0·05	0·05	0·11	2·74
Shikarpur	0·14	0·22	0·25	0·08	0·07	0·21	0·72	1·02	0·46	0·04	0·01	0·17	3·39
Larkana*	0·05	0·14	0·14	0·08	0·10	0·21	0·98	0·93	0·66	0·06	0·03	0·17	3·55
Jacobabad	0·23	0·20	0·26	0·20	0·13	0·36	0·82	0·70	0·28	0·06	0·02	0·18	3·44
Average for Sind	0·12	0·21	0·18	0·07	0·15	0·33	2·63	1·90	0·82	0·06	0·03	0·10	6·65

Stations marked * have their averages taken for 17 years (1914–1930) The rest have those for 30 years (1901–1930)

Rainfall in Kohistan and the Desert Province.—In the matter of the distribution of rainfall in Sind the data for Kohistan are very important, as they give an indication of the periodic supply of rain water in the Malir Basin, which is the main source of Karachi's water supply. Here too the peaks of good rainfall alternate with the years of drought. At Khadeji the record is as follows:—

Year	Khadeji R.G. No. 2 Inches
1914	5·02
1915	3·53
1916	15·60
1917	11·48
1918	0·62
1919	10·05
1920	1·83
1921	12·17
1922	3·86
1923	6·61
1924	5·32
1925	0·75
1926	7·75
1927	8·19
1928	2·94
1929	9·37
1930	8·25
1931	1·24
1932	10·86
1933	15·70
1934	6·22
1935	4·40
Average	6·89

(*Data supplied by the Office of the Karachi Municipality.*)

Thus, though the rainfall in Kohistan is usually scanty, there are years in which it increases to over 15 inches, *e.g.*, in 1916 and 1933. It is even more at Khadeji than at Karachi in some years. There is, therefore, plenty of underground water secured by percolation and absorption in the deeper strata of rock in the dry river basin. (See Appendix III.)

Even in the region called the Thar Desert, there are good, though occasional showers and years of floods. The following is the average rainfall in the different Talukas of Thar Parkar.—

Average rainfall (average of 25 years)	Sinjaro	Mirpur khas	Jamesabad	Dighri	Khipro	Samaro	Sanghar	Umerkot
1910-1935	6·49	9·02	9·50	9·16	7·99	13·5	6·59	9·39

(*Data from P W D , Sind*)

A portion of this rainfall is due to the winter showers, which account for water existing in the number of Dhands or lakes in the Thar and the Pat Sections and affording camel pasture in the cool season

Reasons for Scarcity of Rainfall --Apart from the fact that Sind usually escapes the influence of both the monsoons, there are other reasons of such scarcity or irregularity of rainfall[15]

(1) In the first place, the arrival of the S W monsoon is rather late in Sind and the season is short It does not burst here in May-June, when the land is the hottest (mean maximum temperature at Jacobabad being 113·7° F), but in July when the temperature is lower (mean maximum temperature being 108 5° F), and the chief pressure gradient is over the Peninsular and the Bay of Bengal The reason is that the upper air current over N W India, flowing from the west and north-west during the season is warm and dry with low humidity and this ***descends a couple of thousand feet against the S W monsoon current***

(2) The northern parts of India get very cold in winter, the Himalayan snows melt slowly in early summer and so the high pressure over the area ***takes much time to turn into a low pressure system***, so essential for the necessary indraught Hence the delay in the actual arrival of the rainy season in the Indus valley and the reduction in the number of rainy days Also, the more the snowfall in one winter season on the mountains, the poorer the prospects of rains in the plains in the following summer

(3) As the monsoon season advances, and the lowest pressure is well within the angle between the Kirthar and the Himalayan Mountains, the air can only flow in here from the south and east and so ***only a portion*** of the monsoon current containing a little moisture can pass over the Province

(4) The land being exceptionally and increasingly hot from south to north, *e g* , mean T 85° F at Karachi to 95° F at Jacobabad, ***the humidity is relatively reduced***, from 80% to 50% only. The high temperature is also further increased on account of the dry hot land and the absence of low clouds.

(5) The air current over the N W. ***must rise some*** 3,000 ***ft*** above the sea-level before any appreciable precipitation can take place. Such is not the case in Sind, and the upper layers, being warm and dry, do not

allow formation of low clouds over the land While in North India and in the Ganges basin rainfall increases as we approach high mountains, in the Indus basin the reverse is the case, precipitation decreasing considerably on the western highlands

Variability of Rainfall—Not only is the rainfall in Sind scarce but it is also irregular, so that for every one season of good rains, there are two or three or even more of drought At times, again a whole season's rain falls within a couple of days and there is prolonged scarcity for the rest of the year The result is terrific floods and destruction of crops at one time and severe drought at another "Over the Indo-Gangetic Plain, variability* is at a maximum in Central Sind, which is at once the seat of the most niggardly and also the most variable rainfall in the whole of India The noticeable improvement in reliability is of little, if any, economical significance, for throughout Sind, Bhawalpur and Western Rajputana a variability of over 30 per cent combines with an average rainfall, which is nowhere greater than 15 inches and for the most part is considerably less "[16]

In Sind and Cutch the annual percentage deviation from the average is ± 37 (mean) + 124° (max) – 53° (min), the most unique in the whole of India

ollowing table of comparative variability is significa

Station	Average Annual Rainfall	Variability
Naoshero (Sind)	5"	53%
Cawnpore (U P)	34"	20%
Calcutta (Bengal)	65"	11%
Rohri (Sind)	6"	65%
Sirsa (Punjab)	12"	46%
Lucknow (U P)	35"	28%
Darbhunga (Bengal)	44"	20%
Barisal (Bengal)	62"	16%

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* Variability of rainfall is the degree in which the rainfall of any given year is likely to deviate from the local average either in excess or defect (Blanford).

This shows that while the normal yearly rainfall increases from a minimum in Sind to a maximum in Bengal, the variability is the reverse "The province in which the annual variations as compared with the general average are greatest is Sind and Cutch "[17]

In this region, again, there is variability of *summer rainfall* of 40 per cent to 60 per cent from the desert in the east to the highlands in the west [See Plate I(*b*)]

Even during the different months of the monsoon season, the variability is different in different regions of the Indo-Gangetic Plain, the worst sufferer being Sind —

Month	Region I	Region II	Region III A	Region III B	Region IV
June	> 70	65–75	60–75	60–75	45–60
July	> 60	45–75	10–50	40–50	30–40
August	> 70	40–70	40–50	10–50	35–50
September	> 90	>80	60–75	60–75	15–60
October	>100	>100	>100	>100	>75

Thus the rainfall in the Lower Indus basin is not only scanty but also irregular and unreliable; so one cannot speak of *normal* rainfall figures for any station in Sind. "Within the Middle and Lower Indus lowlands, the so-called *normal* rainfall figures are anything but indicative of conditions from year to year "

In the case of Karachi over a period of a third of a century, the normal rainfall was 6 3 inches though half the season's precipitation was no more than 4·3 inches In three seasons, the rainfall amounted to a little over 20 inches.

V *Cyclical Period*

This leads us to the consideration of a cyclical period in Sind There is no doubt that the floods come periodically but to establish a cycle of a *certain number of* years is a most difficult meteorological problem here Blanford established a cycle of 11 years from certain meteorological calculations which, however, do not tally with the data collected in this region in recent years He marked the relationship between weather and sunspots, the maximum of which occurred at intervals of 11 years " But the actual amount of surface covered at each maximum is very irregular "[18]

Another argument advanced in favour of a cycle of 11 years is that it tallies with the main daily range of magnetic declination, according to Prof. Balfour Stuart But in this case also we have to deal with very irregular curves It may be that there are other unknown influences working out a cyclical period The temperature and rainfall in a particular area are caused by storms and depressions, which cannot be accurately gauged or forecast at present But it can be said with a certain amount of accuracy that any alteration in the solar heat may *modify* the formation of cyclones and so a cyclical period

There is, again, the possibility of connecting years of drought with the years of heavy snow-fall on the Himalayas, as too much snow may cause prolonged suspension of summer rainfall Droughts may also be due to unseasonable persistence of dry land winds Another strange coincidence is that a drought in the Peninsula is followed by one in North India, *e g*, 1876 Deccan drought, 1877 Punjab drought

So far as the region of our study is concerned, a cycle of 11 years is quite out of the question In very recent years a cycle of 6-7 years is noticeable, *viz*, 1902, 1908, 1910, 1913, 1921, 1926, 1932 (See Plates III & IV)

VI *Climatic Change*

Is, then, the climate of Sind also changing? There are several records to show that Sind experienced a better and more congenial climate in prehistoric days "It is related by the chronicles of antiquity that in days gone by, in ages that have long fled, Sind was a lovely land, situated in a delightful climate, a fertile plain, traversed by the beneficent Mihran with large flourishing and populous cities, orchards producing every kind of tree and fruit, and gardens that were the reflections of Iran and the envy of the seven Heavens"[19]

The remains of Mohen-jo-Daro and of other kindred sites in Sind distinctly indicate a wetter Sind in the pre-Aryan period

The admirable researches of Sir Aurel Stein[20] in Baluchistan and Waziristan show that the climate of Central Asia must have been in the past more favourable, especially in Gedrosia where there were impenetrable forests[21]

Again, a favourable climate is an essential condition of high civilisation This has led Sir John Marshall[22] to believe that in the chalcolithic age of Mohen-jo-Daro the rainfall in Sind must have been 15-20 inches average annually. He thinks that the northern storm belt was then deflected by arctic pressure further south At the same time a deflection of the S W monsoon current is also suggested On the whole, all the dry Afrasian belt was covered by westerly rain storms in that age

Dr. C W Normand, Director of the Meteorological Department of India, has opined that more rain in the summer season was possible in Sind and Baluchistan at the time of the Indus Valley Civilisation, "as a very much greater change in meteorological conditions is required to explain a copious rainfall in winter, unless a change in the orography of Sind's surroundings in simultaneously postulated."[23]

Mr Majumdar is also of opinion that from the presence of many drains and pipes and burnt bricks of Mohen-jo-Daro, figures on seals of animals living in moist climate such as rhinoceros, tigers and elephants and of trees on painted pottery, it can be surmised that Sind must have seen wetter years in the milleniums before Christ[24] Remains of elephants and rhinoceros are actually found on the eastern side of the Kirthar Range

Burnt bricks and not baked ones were used in Sind in those prehistoric times Even in the remains of Bahamanabad discovered by Bellasis, such burnt bricks were used suggesting greater rainfall[25]

Raverty has noticed in *Arabic geographers* a reference to the green (*Hariana*) and cultivable lands now lying barren[26] A big forest between Lakhi and Khanpur in Larkana District was actually utilised by the Daudpotras for their Shikargahs

That the climate of Sind has become gradually drier to-day than at the time of Mohen-jo-Daro is also attested by Dr Mackay from the rapid deterioration of bricks, which is now taking place and those beautifully preserved in the buried city "This state of things was due to the fact, that the plain round the city was then well watered and consequently the destroying action of the salt was checked, although as we know the buildings needed frequent repairs"[27]

In this matter of climatic change, the climatic tables, of two sets of normals for the three stations Karachi, Hyderabad and Jacobabad, covering two long distinct periods, are also suggestive (See Appendix II)

Whatever the meteorological conditions of Sind may have been in the past ages, the rainfall recorded for the past five years does not give any indication of a change of climate The year 1933 was only a flood year for Karachi while in 1935 and 1936 the rainfall at the station was decidedly poor, while Hyderabad has fallen below the average

There is a suggestion made by some writers that the Sukkur Barrage which is fully functioning since 1932, would help Sind to secure more rains But such an expectation is too premature Considerable data[28] must be collected and more time must elapse before the meteorologists of Sind can come to any definite conclusion It is not impossible that more extensive water

Latest Rainfall Statistics
India Weather Reviews (1929

Year	Karachi	Hyderabad	Jacobabad
931	0 73	2 01	1·11
932	12 78	4 33	5 24
933	20 11	8 60	5·71
934	8 07	8 35	5 97
935	4 51	3 29	5 30
936	3 73	4 24	3 61
Average	8 32	5 13	4 49

supply, perennial irrigation, afforestation and continuous evaporation may cause slightly greater precipitation of rainfall in Sind in the years to come Says Blanford "Of the influence of local evaporation in enhancing rainfall, one or two instances are given especially that of Yarkand and that of the irrigated tract bordering the Indus in Sind and the lower Punjab"

Summary

In no other region in India are the climatic conditions more unique, irregular and unstable than in the Lower Indus basin It is the driest and hottest of all Indian provinces, aridity being its commonest feature, *e g*, Jacobabad has a mean maximum temperature of 113° F and mean humidity of 41 per cent The thermal equator passes through Sind These conditions are accentuated by its physical features, the Thar Desert in the east, the sea in the south and the Hala-Suleman (Kirthar) Mountains with their peculiar re-entrant angle, in the west and northwest Thus the temperatures are exceptionally high in summer but in winter they are comparatively low The diurnal range of temperature is also great (*e g*, over 45° F in a single day at Jacobabad) Nearest the sea coast, the daily range of temperature is less The monthly range increases from south to north and from summer to winter (*e g*, Jacobabad has a summer range of temperature 42° F and winter range 50° F) The greatest humidity occurs in August, *viz*, 75, but the least in December, *viz*, 58 in Lower Sind and 47 in April in Upper Sind Thus the weather is drier and hotter but more bearable in the north than in the south The skies are generally clear and frost is not uncommon.

While in Upper Sind it is generally calm for nearly half the year, nearer the coast of Sind, the wind velocity is about 15 miles per hour in the monsoon season Dust storms and squally weather are common in the beginning of the two chief seasons The predominant wind direction at Karachi is westerly before the monsoon season begins, but in winter the direction is north-east or north-west In Upper Sind, however, it varies from south-east to north-east in summer and from north-east to north-west in winter

In the matter of rainfall, the region suffers the most It is not only precarious and scanty but also the most variable in India, the orography of Sind being mainly responsible for it What little precipitation it gets is often due to cyclonic storms, caused by eastern and western disturbances, particularly the former The average rainfall is about 7 inches in Lower Sind and about 3 inches in Upper Sind, with only about 8 rainy days in the whole year, July being the rainiest month The greatest peculiarity about the rainfall curve is that after gaps of six or seven years of scarcity, there are peaks of good and at times heavy rainfall, though the cyclical period is hard to determine It is a question whether there is any real progressive climatic change in Sind, as the history of the Province shows that there might have been greater rainfall in the past when forests existed It is equally difficult to say whether the Sukkur Barrage drainage system would influence future rainfall Even with perennial irrigation, afforestation and continuous evaporation it is not certain whether Sind would see wetter days

* * *

The paper is a continuation of the *Geographical Analysis of the Lower Indus Basin (Sind)*, already published in the *Proceedings* * It is illustrated with necessary graphs, sketch maps, etc

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Reliable climatic data for many stations in Sind are hard to obtain For the present Paper they have been collected from the *Gazetteer of the Province of Sind*, and from the publications of the India Meteorological Department, *e g*, *India Weather Reviews*, access to which was kindly allowed by the Meteorological Office, Karachi, also from the records of the Development and Research Department, P W D, Sind, and the Office of the Karachi Municipality, by the courtesy of the chief executive officers

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APPENDIX I

General Weather Conditions in Sind Month by Month

January

Coldest month of the year
Western disturbances affect the region
Cold waves, rain, squally and northerly wind expected
Dust storms and frost also are likely
Mean temperature—Max 74 8° F , Min 50·4° F
Mean rainfall- 12 inches
Mean Baro pressure--30 005
Mean humidity—60%
General wind direction- N E , N W

February

Meteorological conditions similar to those in January
More windy month—Chilly weather
More westerly depressions—Rain expected
Mean temperature--Max 78·8° F , Min 54 2° F
Mean rainfall—·21 inches
Mean Baro pressure—29 950
Mean humidity--59%
General wind direction, N E , N W

March

Dry weather, clear or partially clouded skies
Rather dusty month
Early mornings foggy near the coast
Western disturbances still occur with scattered showers
Mean temperature--Max 88·7° F , Min 63 7° F
Mean rainfall—·18 inches
Mean Baro pressure—29 835
Mean humidity--56%
General wind direction—N W

April

Winter conditions disappear and summer conditions appear
S W wind begins to blow across the region
Dust storms at times, practically no rainfall
Mean temperature--Max 96·6° F , Min. 72·1° F.
Mean rainfall--- 7 inches
Mean Baro pressure—29·712
Mean humidity--56%
General wind direction—S E

May

Arabian Sea storms begin to affect Sind
(Tropical Sea storms of the Arabian Sea enter Sind Coast, once in 12 months)
Practically dry weather Cloudiness increases
Moderate to strong surface winds from S W
Dust storms expected
Mean temperature—Max 102 8° F , Min 78·3° F.
Mean rainfall--·15 inches.
Mean Baro pressure—29·590.
Mean humidity—60%
General wind direction—S E & S W

June

Hottest month of the year
Monsoon condition but with practically no rain
Wind current stronger than in May
Rough seas and swells
Coasting steamers stop sailing
Mean temperature—Max 103 3° F , Min 83 1° F
Mean rainfall— 33 inches
Mean Baro pressure—29 429
Mean humidity—63%
General wind direction—S W & S E

July

Rainiest month of the year
Monsoon current reaches the interior
Humidity is expected to increase
Western depression on rare occasions, wind and rain
Wind current *strong*
Mean temperature Max 99 2° F , Min 82 8° F
Mean rainfall—2 58 inches
Mean Baro pressure—29 391
Mean humidity—72%
General wind direction—S W , S E

August

Milder weather prevails
More cloudy and less rainy month
Visibility is improved Wind direction still, S W
Eastern depressions sometimes occur
Mean temperature—Max 95 3° F , Min 80 2° F
Mean rainfall—1 86 inches
Mean Baro pressure—29 473
Mean humidity—75%
General wind direction—S W S E

September

Receding monsoon
Eastern disturbances expected sometimes
Dust storms and squalls are fewer
Wind velocity gets reduced
Mean temperature—Max 95·4° F., Min 74 4° F
Mean rainfall— 82 inches
Mean Baro pressure 29 624
Mean humidity— 73%
General wind direction—S W S E

October

Dry and clear month
Only rare Arabian Sea depressions
Practically no rain
Temperature rises slightly at times
Wind direction now alters
Sea is smooth and coasting steamers begin to ply
Mean temperature—Max 94 9° F , Min 70·0° F
Mean rainfall— ·06 inches
Mean Baro pressure—29 799
Mean humidity—63%
General wind direction—S W., N E

November
- Wind direction changes from W–S W to N–N W, N E
- Pleasant month Without any showers of rain
- Western disturbances on occasions bring drizzles rarely
- Mean temperature—Max 87·4° F, Min 59·7° F.
- Mean rainfall— 03 inches
- Mean Baro Pressure—29 937
- Mean humidity—57%
- General wind direction—N E, N W

December
- Squally weather expected
- Western disturbances come in at times
- Pleasant month
- Wind directions changes to N and N E
- Winter showers expected
- Sea very smooth
- Mean temperature—Max 77 6° F, Min 51 8° F.
- Mean rainfall— 10 inches
- Mean Baro pressure— 30 010
- Mean humidity—60%
- General wind directions -N W, N E

N B—The above summary of the weather conditions for the whole of Sind is based upon the climatic data for the three main stations in Sind, utilised in the body of the paper *viz* Karachi, Hyderabad and Jacobabad

APPENDIX II

Temperature, Barometric Pressure and Humidity Normals

	Karachi (Manora)				Hyderabad				Jacobabad			
	6 Temperature		22 Pressure	6 Humidity	31 Temperature		22 Pressure	22 Humidity	23 Temperature		22 Pressure	22 Humidity
	(Max)	(Min)		%	(Max)	(Min)		%	(Max.)	(Min)		%
January	75 7	58 5	30 095	83	76 2	50 6	30 006	57	73 0	43 2	29 915	64
	76·0	*56 7*	*30 090*	*61*	*75 6*	*50 5*	*30 006*	*61*	*72·7*	*44 1*	*29·921*	*65*
February	78 2	61 5	30 047	66	80 5	54 0	29 953	56	77 8	48 2	29 855	55
	77·7	*59 5*	*30 062*	*67*	*80 4*	*54 0*	*29 941*	*58*	*77 5*	*49 1*	*29 847*	*54*
March	81 8	66 3	29 954	67	92 6	64 0	29 848	50	90 7	59 7	29·743	45
	83 1	*67 3*	*29 938*	*71*	*92 5*	*63 5*	*29 834*	*53*	*90 7*	*60 5*	*29 733*	*45*
April	85 3	74 0	29 836	79	102 0	72 1	29 719	47	99 6	69 7	29 603	41
	87 0	*74 1*	*29 831*	*76*	*101 2*	*71 6*	*29 710*	*52*	*101 8*	*70 6*	*29·597*	*41*
May	88·8	78 3	29 737	80	107 2	78 2	29 601	54	112 0	78 3	29 466	42
	90 2	*78 9*	*29 723*	*75*	*107 0*	*78 1*	*29 589*	*55*	*111 3*	*78 1*	*29 460*	*43*
June	91 0	82 4	29 577	80	104 2	81 7	29 452	62	113 9	84 3	29 316	55
	91 6	*82 4*	*29 560*	*79*	*104·6*	*82 0*	*29 432*	*64*	*113 7*	*85 1*	*29 295*	*57*
July	88 2	80·4	29 540	83	99 2	80 9	29 410	68	108 4	84 6	29 280	66
	89 6	*81 3*	*29 522*	*82*	*99 6*	*81 7*	*29 391*	*69*	*105 5*	*85·6*	*29 260*	*65*
August	85 5	77 7	29 621	85	95 9	79 0	29 486	70	104 6	81 9	29 361	72
	86 7	*78 5*	*29 599*	*84*	*99 5*	*79 6*	*29 467*	*72*	*103 9*	*82 5*	*29 353*	*71*
September	85 6	75 8	29 765	82	97 4	76 2	29 635	68	103 7	76 2	29 515	71
	86 8	*76 9*	*29 747*	*82*	*96 7*	*76 6*	*29 619*	*70*	*102 9*	*76 0*	*29 506*	*68*
October	86 6	73 0	29 918	73	97 9	70 1	29 809	56	99 2	63 2	29 709	56
	86 5	*73 5*	*29 902*	*74*	*97 5*	*70 8*	*29 796*	*61*	*98 8*	*65 7*	*29 699*	*56*
November	84 3	66 7	30 039	66	89 1	58 9	29 942	52	87 8	51 8	29 856	57
	86 1	*65 3*	*30 024*	*62*	*88 9*	*60 5*	*29 935*	*55*	*87 3*	*53·5*	*29 852*	*56*
December	78 2	59 6	30 100	58	79 0	52 3	30 025	55	78 7	44 3	29 938	66
	79 2	*58 8*	*30 090*	*58*	*78 2*	*52 1*	*30 012*	*59*	*75 5*	*44 7*	*29 930*	*63*
Annual	84 1	71 2	29 853	73	93 4	68 2	29 741	58	95 6	65 5	29 630	58
	85·5	*71 2*	*29 839*	*73*	*93 3*	*66 7*	*29 728*	*61*	*95 5*	*66 4*	*29 621*	*57*

The figures italicised are monthly and annual *normals* of 30 years (1901–1930) obtained by me from the data gathered from *India Weather Reviews* (*India Met. Dept*), while the others are monthly and annual normals (Published in *Memoirs Ind Met. Dept.*, Vol 22, Pt III, Calcutta, 1914) The figures given at the top of each column show the number of years of which the latters are normals At Karachi, the conditions are nearly the same except a slight rise in the maximum T Humidity is doubtless increased at Hyderabad while at Jacobabad the range of T, is reduced, so also the barometric pressure and humidity

Rainfall Normals

Station	No of years taken	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct.	Nov	Dec	Annual
Nagar Parkar	14	0·03	0·22	0·10	0·06	0·06	0·42	5·70	5·27	1·20	0·04	0·10	0·03	13·23
	30	*0·03*	*0·15*	*0·07*	*0·01*	*0·27*	*0·64*	*6·16*	*4·52*	*2·49*	*0·39*	*0·04*	*0·04*	*14·85*
Tatta	32	0·28	0·42	0·13	0·18	0·07	0·68	4·00	1·83	0·54	0·00	0·14	0·07	8·34
	30	*0·11*	*0·37*	*0·21*	*0·04*	*0·21*	*0·61*	*4·48*	*2·09*	*0·58*	*0·02*	*0·04*	*0·05*	*8·88*
Karachi (Manora)	31	0·63	0·48	0·23	0·17	0·08	1·03	2·95	1·39	0·51	0·00	0·17	0·15	7·79
	30	*0·31*	*0·46*	*0·34*	*0·07*	*0·10*	*0·57*	*2·76*	*1·65*	*0·78*	*0·03*	*0·10*	*0·15*	*7·51*
Umerkot	32	0·17	0·13	0·15	0·09	0·06	0·56	3·00	2·32	0·96	0·00	0·05	0·04	7·53
	30	*0·09*	*0·14*	*0·17*	*0·01*	*0·17*	*0·36*	*3·79*	*2·72*	*1·34*	*0·13*	*0·01*	*0·03*	*8·96*
Hyderabad	41	0·24	0·28	0·15	0·06	0·13	0·51	3·17	2·06	0·58	0·00	0·09	0·05	7·32
	30	*0·12*	*0·30*	*0·28*	*0·05*	*0·15*	*0·36*	*3·48*	*2·12*	*0·93*	*0·00*	*0·03*	*0·10*	*7·98*
Naoshero	20	0·25	0·31	0·21	0·03	0·07	0·48	1·15	1·15	0·37	0·00	0·02	0·10	4·12
	30	*0·15*	*0·22*	*0·18*	*0·03*	*0·15*	*0·30*	*1·20*	*1·11*	*0·67*	*0·00*	*0·02*	*0·13*	*4·26*
Sehvan	31	0·35	0·32	0·13	0·19	0·15	0·53	1·66	1·31	0·31	0·03	0·08	0·09	5·15
	30	*0·23*	*0·27*	*0·14*	*0·14*	*0·08*	*0·28*	*2·14*	*1·22*	*0·72*	*0·00*	*0·03*	*0·16*	*5·41*
Sukkur (Rohri)	32	0·25	0·26	0·19	0·18	0·09	0·14	0·74	1·01	0·08	0·00	0·08	0·10	3·12
	17	*0·04*	*0·15*	*0·14*	*0·03*	*0·17*	*0·06*	*0·86*	*0·90*	*0·18*	*0·05*	*0·05*	*0·11*	*2·74*
Shikarpur	32	0·29	0·36	0·29	0·16	0·12	0·13	0·69	1·07	0·20	0·00	0·18	0·16	3·58
	30	*0·14*	*0·22*	*0·25*	*0·08*	*0·07*	*0·21*	*0·72*	*1·02*	*0·46*	*0·04*	*0·01*	*0·17*	*3·89*
Jacobabad	42	0·33	0·32	0·28	0·16	0·13	0·15	1·13	1·17	0·19	0·01	0·08	0·11	4·06
	30	*0·23*	*0·20*	*0·26*	*0·20*	*0·13*	*0·36*	*0·62*	*0·70*	*0·28*	*0·06*	*0·02*	*0·48*	*3·44*

The figures italicised are normals of more recent years, obtained by me from the data gathered from *India Weather Reviews (Ind. Met Dept.)*, while the others are those published in *Mem Ind Met Dept*, Vol 22, Pt I Calcutta, 1913

It must be noted that there is a tendency of increasing rainfall at some stations in Lower and Middle Sind and that this increase is chiefly in the summer rains (especially in July).

APPENDIX III

Comparison of Annual Rainfall at Karachi (Manora) and in Kohistan

(See Plate V)

Year	Karachi and Manora	Kohistan
1896	11 60	1 38
1897	12 24	10 47
1898	4 03	4 06
1899	0 83	0 15
1900	2 14	8 05
1901	2 05	3 19
1902	20 76	16 15
1903	3 86	6 35
1904	4 59	3 21
1905	3 09	4 99
1906	8 93	9 70
1907	8 15	12 25
1908	7 03	23 09
1909	7 03	3 79
1910	12 63	12 75
1911	4 72	9 0
1912	0 39	3 35
1913	13 50	31 55
1914	9 43	6 28
1915	2 22	0 85
1916	22 32	13 38
1917	5 52	16 21
1918	1 87	2 01
1919	2 59	9 63
1920	1 44	3 16
1921	16 35	18 44
1922	1 98	3 65
Average	6 92	8 96

(*Data obtained from the Gazetteer of the Province of Sind* B Vol I.)

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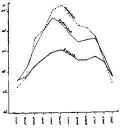
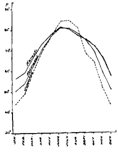
MEAN MAXIMUM TEMPERATURE
FOR 30 YEARS 1901-1930

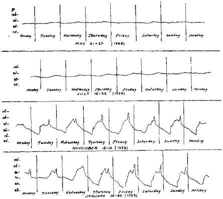


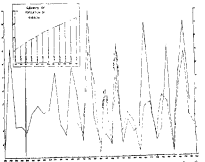
MEAN MINIMUM TEMPERATURE
FOR 30 YEARS 1901-1930



(Data from India Meteorological Dept.)

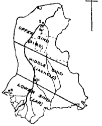
THERMOGRAPHS AT KARACHI (N E D COLLEGE)
1928-29



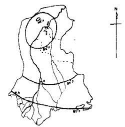


ANNUAL RAINFALL AT KARACHI (MANORA) AND KIAMARI (Data from Karachi Municipality)

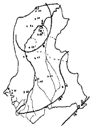
CLIMATIC DIVISIONS OF SIND.



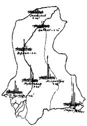
JULY TEMPERATURE (MEAN) IN SIND



RAINFALL IN SIND

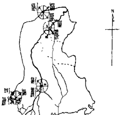


MONTHLY RAINFALL IN SIND

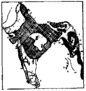


(Data from India Meteorological Dept.)

SURFACE WINDS OVER SIND

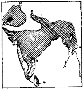


JULY RAINFALL

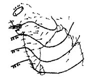


JULY TEMPERATURE

(Blanford's "Climates of India & Ceylon")

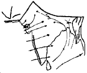


JULY WIND & PRESSURE

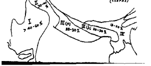


(Blanford's "Climates of India & Ceylon)

STREAM LINES DURING MONSOON



VARIABILITY SUMMER RAINFALL
(INDO-GANGETIC PLAIN)
(Clark's)



Maneck B. Pithawalla

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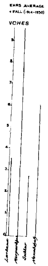
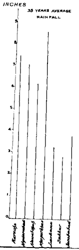
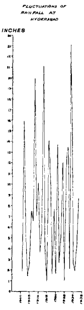
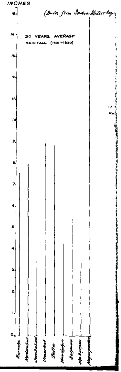
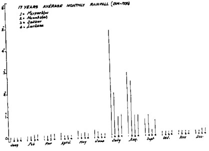
Maneck B. Pithawalla

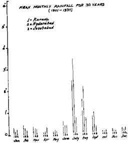


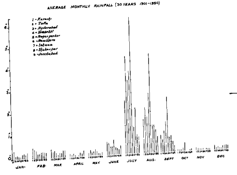






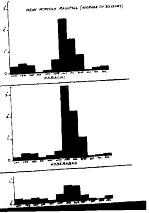


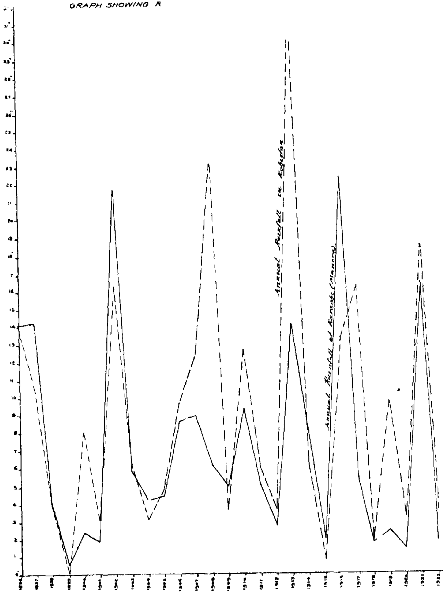




(Data from India Meteorological Dept.)

Maneck B Pithawalla




GRAPH SHOWING R
Annual Rainfall in Kohistan
Annual Rainfall at Karachi (Manora)
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EXPLANATION OF PLATES, SKETCH-MAPS, GRAPHS, ETC

I (*a*) Sketch-maps of Sind showing –
- (1) Climatic divisions
- (*2*) July temperature (Mean)
- (*3*) Rainfall distribution
- (4) Surface winds

(*b*) Sketch-maps of India showing—
- (1) July rainfall (Blanford)
- (*2*) July temperature (Blanford)
- (3) Variability of summer rainfall (Clerk)
- (4) July wind and pressure (Blanford)
- (5) Stream lines during monsoon (Blanford)

II Graphs showing-
- (1) Mean maximum temperature at Karachi Hyderabad and Jacobabad
- (*2*) Mean minimum temperature at Karachi, Hyderabad and Jacobabad
- (*3*) Thermograms at Karachi
- (4) Annual rainfall at Karachi (Manora) and Khadeji and Growth of Population of Karachi

III Graphs showing--
- (*1*) Fluctuations of rainfall at Hyderabad
- (*2*) Average annual rainfall at Karachi and other stations

IV Graphs showing--
- (1) Average monthly rainfall at Karachi and other stations
- (*2*) Mean monthly rainfall at Karachi, Hyderabad and Jacobabad

V Graph showing annual rainfall at Karachi (Manora) and Kohistan

ECHINOIDS FROM THE BAGH BEDS.

By G W Chiplonker, M Sc

(Research Student, Department of Geology, Benares Hindu University.)

Received May 28, 1937

(Communicated by Prof L Rama Rao, M.A., F G S)

Introduction

The Cretaceous age of the Bagh Beds was first recognised by Col Keatinge[33] in 1856 from the fossils he collected from the neighbourhood of Chirakhan (lat 22° 22′ 30″, long 75° 7′ 30″) Of the fossils from these beds, only the echinoids and the ammonites have so far received proper attention. Duncan[23,24] on the basis of his study of, the echinoids from these beds considered them to be of Cenomanian age This conclusion was accepted by W T Blanford,[7] R D Oldham[47] and D N Wadia [57] By others, however, these beds have been variously assigned an age from Albian to Senonian [8,20,29,44,45,58,65]

While working on the echinoids from the Bagh Beds collected by the late Prof K K Mathur and by the present writer, a few new forms have been discovered These, along with such of the forms already known as required some additional remarks on the basis of the new collections, are described below

Of the echinoids described by Fourtau[29] the name *Hemiaster oldhami* being pre-occupied for a Mæstrichtian species from Baluchistan described by Noetling,[46] the species is here renamed *H fourtaui* The other two spatangid species were assigned by Fourtau to the genus *Opissaster*, Pomel, because of their ambulacral petals sinuous and unequal at the poriferous zones [29] This genus is, however, regarded by Duncan[25] and R T Jackson[31] as an invalid one The genus was evidently established by Pomel[17,35,49] to include *Hemiaster* species having *Schizaster*-like physiognomy but devoid of the latero-sub-anal fasciole Pomel himself, later on included in this genus, species with two, three or four pores, high inter-ambulacral plates and petals flexuous or non-flexuous and excavated or not The confusion thus created led Lambert[35,40] to revise the genus as "having two genital pores, flexuous ambulacral petals and ranging from Eocene to Recent"

The Indian specimens under consideration certainly do not belong to *Opissaster* They have flexuous ambulacrals and an apical disc with four perforate genital plates, the madreporite on the right anterior genital plate extends centrally but does not separate the posterior genital plates They thus belong to the genus *Hemiaster*

Description of the Species

Salenia mathuri,* sp nov

Pl VI, Figs *3a–3d*

Dimensions —	Diameter	Height	Height/Diameter
	11 0 mm	6 8 mm	6 18/10

Description —Test is much depressed, ambitally tumid, very feebly convex superiorly and rounded inferiorly Small peristome is about ⅓ of the diameter of the test, branchial incisions are well marked Apical disc is large and polygonal being about 66 1 per cent of the diameter of the test Periphery is raised with sutures of genital and ocular plates strongly incised Genital plates are as broad as high, well angulated adorally, ornamented with radial grooves and ridges and unequally divided, with the outer part markedly smaller. Large elliptical genital pores are imperceptibly rimmed, adorally eccentric and placed in feeble depressions Madreporite is on the right anterior genital plate and roughly trapezoidal in shape running towards the suture with ocular III Sur-anal plate is larger than the genital ones but similarly ornamented Ocular plates are radially grooved, twice as broad as high and feebly adorally convex, with adorally eccentric ocular pores At the periphery, ocular plates are broader than the genital ones. The ocular plate I is insert Periproct is broadly elliptical and deeply excavates the sur-anal plate, reaching the pores on the genital plates 1 and 2

Ambulacral areas are wide and slightly flexuous Pore-pairs are oblique with pores separated by granules Adapically pore-pairs are uniserial over three-fourths of the ambulacral length, from halfway between ambitus and peristome they become gradually biserial attaining distinct triserial disposition on the first three adoral plates This transition is accompanied by an appreciable widening of the ambulacral area, swelling of the inter-poriferous tubercles and widening of the miliary zone On approaching the peristome the inter-poriferous zone is narrowed slightly with corresponding decrease in the size of the last three tubercles, while the triserial arrangement maintains the width of the ambulacral areas The inter-poriferous zone carries two rows of small tubercles and microscopic warts disposed zig-zag in the middle area

Inter-ambulacral areas are three times as wide as the ambulacral ones and carry two series of high plates, four or five per series. The primary tubercles are crenulate, imperforate and mameloned , the scrobicular rings are of the "Quadrate" type of Arnaud[6] The median zone with miliary granules is slightly narrower than the inter-poriferous zone Each plate in the mid-zone abuts against 8 to 10 ambulacral plates at the ad-ambulacral suture

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* **This species is named after the late Prof K K. Mathur**

Comparison —This species differs from the associated S ***keatingei***, Fourtau[23,24,29] chiefly by its higher but discoid form , apical disc and peristome smaller , lower and well-angulated genital plates , and conspicuously sudden increase in the width of ambulacral areas and miliary zone, and by the size of the inter-poriferous tubercles

S ***prestensis***, Desor[15,16,18,32,37,38,42,43] from Aptian of Algeria and Western Europe and S ***scutugera***, Gray[1,3,5,6,13,15,18,19,30,53] from Cenomanian of Charente, Tunis and Algeria differ from the present species by their relative dimensions and nature of the corona and apical disc

S *cylindrica*, Arnaud[6] from France differs from the species described here by its taller test, wider peristome and a smaller apical disc , otherwise these two forms are very closely similar

S ***mamillata***, Cotteau[14,15] from the Aptian of Aube has its apical disc sculptured very similar to that of S ***mathuri*** , but differs in relative dimensions and nature of the inter-ambulacral plates

S ***maxima***, Arnaud[6,15] from Senonian of Charente has its apical disc and ambulacral areas very similar to those of the present species , but they can be distinguished one from the other by their relative proportions, lower inter-ambulacral plates and wider inter-ambulacral areas

N.B —All the type specimens are preserved in the Department of Geology, Benares Hindu University

Diplopodia (*Tetragramma*) *aff* *micropyga*, Fourtau

Pl VI, Figs *1a*–*1b*

Dimensions —	Diameter	Height	Height/Diameter
	27 2 mm	10 0 mm	3 7/10

Description —Test is discoid with small peristome in a conspicuous depression Apical disc is not preserved but will be about one-thirds of the diameter of the test

Ambulacral areas are narrow with poriferous zones slightly flexuous , pairs of rounded pores are oblique in arcs of four, being uniserial at the ambitus and diplopodous at half the distance from the peristome and the apical disc towards the ambitus Plates consist of three primaries and one adoral demi-plate, the primary next to the demi-plate being the largest.

Two series of 16 or 17 primary perforate crenulate, scrobiculed tubercles cover the inter-poriferous zone, miliary granules being absent

Wide inter-ambulacral areas carry six series of primary perforate crenulate tubercles with scrobicular rings Disorderly granules in the median sutural area die out dorsally above the ambitus The tubercles are almost equal to those of the inter-poriferous zones Only the middle two series with 15 or 16 tubercles reach the apical disc, the lateral series dying out successively above the mid-zone Internal ranges of tubercles show that this specimen belongs to Lambert's group of *Tetragramma zumoffeni*, Cotteau [22,24,27]

Comparison —*T almerai* (Lambert)[24,27] from Aptian of Barcelona differs from the present species by its more depressed, polygonal test and weaker doubling of the pore-pairs

Pseudodiadema roissyi (Cotteau)[19] from Cenomanian of Sarthe has its test higher, primary tubercles more differentiated and ambulacral areas wider

A very close affinity is found between the present specimen and *D micropyga*, Fourtau[30] from the lower Cenomanian of Egypt, the bad preservation of the specimen described here however leaves their identity in doubt

Echinobrissus cf anguiier, Gauthier

Description —The specimens available for study are not well preserved The test is longer than broad, anteriorly tumid and feebly tapering, and more rounded than truncated behind Periproctal groove reaches upto half the distance between the apex and the slightly indented posterior border Summit of the test coincides with the apical disc at three-fifths length from the front Peristome is in a depression at two-fifths length from the front Ambilacrals are lanceolate with conjugate, elongate pores and the inter-poriferous zones are narrower than the poriferous ones

Comparison —These specimens offer the closest resemblance to the variety, *E anguiier*, Gauthier[18] from upper Cenomanian of Algeria

Echinobrissus sp indet

These specimens are also poorly preserved They differ from those described above by their having a test almost squarish in outline with a very obtusely rounded anterior border Distally the ambulacrals are slightly deflected outward

These specimens resemble more closely to the variety of *E anguiier*, Gauthier[18] from the Albian and middle Cenomanian of Algeria

It is significant that these two echinobrissi should occur in the Bagh Beds at the same horizon, their Algerian allies being found in successive horizons, i e, in Albian to middle Cenomanian and upper Cenomanian Though with better material to work upon, these two forms may have to be merged into one species, in their present state of preservation they are best described separately

Hemiaster fourtaui,[†] nom nov

1887 *Hemiaster cenomanensis*, Duncan non Cotteau—*Rec G S I*, **20**, p 91

1918 *Hemiaster oldhami*, Fourtau non Noetling—*Rec G S I*, **49**, p 46, pl 2, figs 2–3

This species is recorded here under a new name, its old name being pre-occupied for a Mæstrichtian species from Baluchistan[44] It differs from the Baluchistan species mainly by its test being widest behind the middle, narrower and strongly excavated anteriorly, superior face sloping more gradually to the front than behind, apical disc more eccentric behind, paired petals less divergent and peripetalous fasciole more regular

Hemiaster holo-ambitatus, sp nov

Pl VI, Figs *4a*–*4c*.

1887 *Hemiaster similis*, Duncan non d'Orbigny nec Cotteau nec Oldham —*Rec G S I*, **20**, p 92

1918 *Opissaster sp indet*—*Rec G S I*, **49**, p 51, pl 2, fig 4

Test is oval, almost vertically truncated behind and rounded in front Apical disc is at one-thirds length from behind, rather compact with four perforate genital plates, the madreporite on the right anterior genital plate extending centrally but not separating the posterior genital plates

Odd ambulacre is in shallow, narrow sulcus which stops well above the ambitus Rounded pores are separated by granules, the flexuous paired petals are in shallow grooves, with pores arranged in "Chevrons" Posterior petals are about three-fifths of the anterior ones The biggest of the specimens has 16 pore-pairs in the posterior petals and 28 in the anterior ones

Periproct is towards the top of the posterior face Peristome is at one-thirds length from the front Peripetalous fasciole crosses the odd ambulacre well above the ambitus

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[†] This species is named after R. Fourtau who had previously described this species under a different name.

This species combines the characters of *Hemiaster* sensu stricto and of *Integraster*, Lambert and Thiery[40]

Comparison—Due to bad preservation of the specimens available for study, Fourtau had wrongly allied this species with *H vignesi*, Cotteau from the east of Jordon[41] But it has much lower test, more developed ambulacrals and apical disc more eccentric behind

The present species differs from *H stella* (Morton)[4,9–12,21,23,54] from upper Cretaceous of U S A by its test medianly widest and anteriorly more tumid, upper face sloping forward more gradually, anterior groove narrower and shorter, and petals more flexuous

Narrower form, shallower grooves and flatter inferior face distinguish this species from *H asterias*, Forbes[14,21,26] from the Albian of Folkstone and Yonne

From *H rutoti*, Lambert[26] from Senonian of Belgium, this species differs by its petals more flexuous, test ambitally oval and inferiorly more convex

Hemiaster meslei, Peron and Gauthier

1878 *Hemiaster meslei*, Peron and Gauthier—*Ech foss Algeria*, fasc **4**, p 10, pl 2, figs 5 8

1889 *Hemiaster meslei*, Peron and Gauthier—*Ech foss Tunisie*, p 12

1914 *Hemiaster meslei*, Peron and Gauthier—*Cat Invert foss Egypt Pal Ser*, No 2, p 81

1932 *Hemiaster meslei*, Peron and Gauthier—*Mem Soc Geo France*, No 16, n s VII, fasc **4**, p. 12

The specimens from Bagh Beds differ from the type of Peron and Gauthier from the Cenomanian of Algeria by their very slightly broader test and a little less conspicuous anterior indentation Such differences, however, are not unexpected in species having such a wide geographical range

Hemiaster cf thomasi, Peron and Gauthier

Pl VI, Fig 2

Dimensions—	Length	30·6 mm	22·5 mm	20 0 mm	17 0 mm
	Breadth	30·6 ,,	21·4 ,,	21 0 ,,	16 4 ,,
	Height	19·8 ,,	14 0 ,,	15 0 ,,	11·0 ,,

Description—Test is trigonal, widest at one-fourths length from the deeply indented front, rapidly narrowing behind, with superior face more or less regularly raised

Pores in the odd ambulacre are oval, placed in "Chevrons" and separated by granules An internal row of scrobiculed tubercles rises up along the poriferous zones for half the length of the groove, above which they die out gradually Two rows of granules follow the horizontal sutures of the ambulacral plates In the paired petals, the pore-pairs are oblique at the proximal ends, straight in the middle and in "Chevrons" at the distal ends Dorsally to the pore-pair a line of granules passes along the horizontal sutures Posterior petals are three-fourths of the anterior ones The biggest specimen has 36 pore-pairs in the posterior petals and 41 in the anterior ones Inter-poriferous zones are narrower than the poriferous ones

Periproct is towards the top of the posterior steeply truncated face Peristome is at one-fourths length from the front Peripetalous fasciole crosses the odd ambulacre just above the ambitus and shows no inflexions.

Apical disc is sub-central, rather broad with four perforate genital plates Madreporite is on the right anterior genital plate and extends posteriorly so as to separate the posterior genital plates Ocular III penetrates between the genital plates 2 and 3

Comparison.—This species has a very distinctive form and need be compared only with *H thomasi*, Peron and Gauthier[18,39] from the Senonian of Algeria The Algerian species, however, attains twice the size of the Indian form, its inferior face is more inflated, superior face more raised, test a little broader and the posterior petals a little longer.

Discussion and Conclusions

The accompanying table summarises the vertical distribution and the affinity-relations of the echinoids from the Bagh Beds with those from Europe, North Africa and Western Asia It will be seen that some of the species show close affinities with co-Cretaceous forms and appear to be ancestral to some meso-Cretaceous species *Placenticeras mintoi*, Vredenburg is closely related to *P uhligi*, Choffat and *P saadense*, Peron and Thomas. The appearance of the genus *Hemiaster* in the Albian coupled with these relations of the echinoids and ammonites led Fourtau to regard upper Albian (upper Gault of the British Stratigraphers) rather than lower Cenomanian as the more probable age for the Bagh Beds[10,19] Such a view was not unjustified, considering that the material with which Fourtau had to deal consisted only of the few type specimens in the collection of the Geological Survey of India.

With the extensive collection at the disposal of the present writer it has been possible to carry out a detailed study of these echinoids. Besides the eight species previously known to be represented in these beds, six new and important forms are now added to the list, thus giving a basis much more definite, than was possible hitherto, for the correlation of these beds with those outside India

Among such valuable forms is *Diplopodia cf micropyga*, Fourtau showing lower Cenomanian affinities [20] The genus *Diplopodia*, McCoy, not known to survive the Cenomanian (lower Chalk)[21,40] fixes Cenomanian as the upper age limit for the echinoid fauna of the Bagh Beds Four out of five species of *Hemiaster* recorded from these beds of the Narbada valley belong to the sub-genera *Proraster*, *Mecaster* and *Integraster* all of which make their first appearance in the Cenomanian[40], obviously, this gives the lower age limit for the beds under consideration

Hemiaster fourtaui, nom nov, by far the commonest of the echinoid species from these beds, has its nearest ally *H luynesi*, Cotteau in the Cenomanian of Palestine *H meslei*, Peron and Gauthier, though not very abundantly represented in the Bagh Beds, occurs in the Cenomanian of Algeria, Tunis and Egypt [18,28,39,53] *H sub-similis* (Fourtau)[24,39] and *H. cf thomasi*, Peron and Gauthier[18,39] have their near relations in the Senonian of Persia and Algeria respectively

Vredenburg[65] regarded his *Placenticeras mintoi* as being very closely related to *P tamulicum*, Stoliczka from the Trichinopoly stage (lower Senonian) of the South Indian Cretaceous It is also closely related to *P uhligi*, Choffat[54 56] and *P saadense*, Peron and Thomas[54,55] of which the latter is a Cenomanian form, the former ranging from Gault to lower Cenomanian

Though the genus *Hemiaster* makes its appearance in the Albian, its species from the Bagh Beds, as is shown above, cannot certainly be dated older than the Cenomanian Thus taking into consideration the affinities of these echinoid species in general, the more appropriate age for the Bagh Beds, so far as the present study shows, will be lower Cenomanian rather than upper Albian

P N Bose[8] was inclined to regard the different subdivisions of the Bagh Beds as representing distinct stages approximately equivalent to those of the Cretaceous Series of South India The vertical distribution of the echinoid species as given in the accompanying table is, however, quite contrary to this idea The different constituents of this series of the Narbada valley must be considered, as Duncan has mentioned,[24] to belong to a single geological age, the differences being due more to variations in the lithological facies than to geological time.

Table showing the Vertical Distribution and Affinity-Relations of the Echinoids from Bagh Beds

No	Species from Bagh Beds	Related species with stratigraphical position	Nodular Limestone	Lower Coralline Limestone	Deola Chirakhan Marl	Upper[51] Coralli Limestone
1	*Dorocidaris namadica*, Duncan	*Dor julieni*, Gauthier Aptian of Algeria			•	•
2	*Salenia keatingei*, Fourtau	*S mamillata*, Cotteau Aptian of France			•	
3	*S mathuri*, sp nov	*S cylindrica*, Arnaud Aptian Albian-of France			•	-
4	*Cyphosoma namadicum*, Fourtau	*C peroni*, Cotteau, Barremian of France and Switzerland		•	•	•
5	*Orthopsis indica*, Duncan	*O repellini*, Desor, Barremian Aptian of France, Portugal and Switzerland			•	
6	*Diplopodia (Tetragramma) aff micropyga*, Fourtau	*D micropyga*, Fourtau, Lower Cenomanian of Egypt			•	
7	*Echinobrissus haydeni*, Fourtau	*E eddisensis* Gauthier, Aptian Albian of Algeria and Tunis	•	•	•	•
8	*E cf anguier*, Gauthier	*E anguier*, Gauthier var, upper Cenomanian of Algeria		•	•	•
9	*E sp indet*	*E anguier*, Gauthier, var, Albian-middle Cenomanian of Algeria		•	•	•
10	*Hemiaster Fourtaui*, nom nov	*H luynesi* Cotteau Cenomanian of Palestine	•	•	•	•
11	*H (Proraster) subsimilis* (Fourtau)	*H Morgani* Cotteau and Gauthier, Senonian of Persia	•	•	•	•
12	*H holoambulatus*, sp nov	*H asterias* Forbes Albian of Yonne and Folkstone and *H rutoti*, Lambert, Senonian of Belgium	•	•	•	•
13	*H (Mecaster) meslei*, Peron & Gauthier	*H meslei*, Peron and Gauthier, Cenomanian of Algeria, Tunis and Egypt		•	•	•
14	*H (Mecaster) cf thomasi*, Peron and Gauthier	*H thomasi*, Peron and Gauthier Senonian of Algeria		•	•	•

Acknowledgments

In conclusion, I have to express my indebtedness to the Council of the Benares Hindu University for the grant of a Research Scholarship during which period part of the present work was carried out It is a pleasant memory to recall the kind encouragement that I received at the hands of the late Prof K K Mathur My grateful thanks are also due to Dr Raj Nath, Head of the Department of Geology, for his kind interest in the present work and to the Director, Geological Survey of India, for permission to work in their Museum and Library

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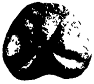

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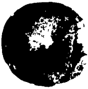
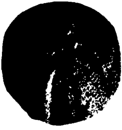


1a

1b



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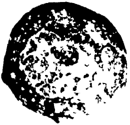
3a



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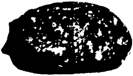

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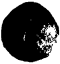

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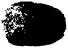

4b

EXPLANATION OF PLATE VI

Fig 1—*Diplopodia (Tetragramma) aff micropyga*, Fourtau, (*a*) inferior view, natural size, (*b*) side view, natural size (B H U No E/4)

Fig 2—*Hemiaster cf thomasi*, Peron and Gauthier, upper view, natural size. (B.H U No E/12)

Fig 3—*Salenia mathuri*, sp nov, (*a*) superior view natural size, (*b*) same approximately 3 5 times natural size, (*c*) side view, natural size, (*d*) same approximately 3 5 times natural size (B H U No E/3)

Fig 4—*Hemiaster holoambitatus*, sp nov, (*a*) superior view, natural size, (*b*) side view, natural size, (*c*) apical view, approximately 3 5 times natural size (B H U No E/10)

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Papers Communicated for the Nineteenth Scientific Mee
to be held on Saturday, the 4th September 1937, at 5-15 P.M., in the
Central Building of the Indian Institute of Science, Bangalore

SECTION A

No	*Title of the Paper*	*Author or Authors*
1	Einige diophantische probleme und Zahlentheoretische resultate	By Prof Dr Alfred Moessner (Com by Sir C V Raman)
2	On the emission and absorption band spectra of selenium	By Dr R K Asundi and Mr Y P Parti
3	Generalised action functions in Born's electro-dynamics	By Prof B S Madhava Rao
4	Generalisation of a theorem of Davenport on the addition of residue classes	By Dr S S Pillai (Com by Dr S Chowla)
5	The Condensation of aldehydes with malonic acid in the presence of organic bases—Part IX The condensation of β-hydroxynaphthaldehyde (2-hydroxy-1-naphthaldehyde)	By Prof K C Pandya and Mr Toquir Ahmad Vahidy
6	The Replication of an experiment I Identical Samples from a binomial population	By Dr S R Savur

SECTION B

No	*Title of the Paper*	*Author or Authors*
1	Cytogenetic aspects for transferring the virus localization ability of *Nicotiana* species at the background of *Nicotiana Tabacum*	By Prof Dr Dontcho Kostoff (Com by Prof C R Narayan Rao)
2	Fungi of Allahabad, India, Part III ..	By Messrs J H Mitter and R N Tandon (Com by Dr Shri Ranjan)

ON *PROTOCYATHEA RAJMAHALENSE* SP. NOV., A CYATHEACEOUS TREE-FERN, WITH NOTES ON THE GEOLOGICAL DISTRIBUTION OF THE CYATHEACEAE.

BY KURIEN JACOB, B A , M Sc ,
Department of Botany, University of Lucknow

Received May 24, 1937
(Communicated by Prof B. Sahni, SC.D., F R S)

1 *Introduction.*

THE specimens described below were collected in December 1934 in the company of my friend, Mr. R N Mehrotra, M Sc , from certain plant-bearing beds at Sakrigalighat, situated about one mile north of Sakrigali railway station in Behar (see map in Sahni and Rao[1]) The collection from this locality was supplemented the following winter, when I had the privilege of accompanying Prof. Sahni to this particular locality A third visit was made in December 1936 The specimens described in the present communication appeared to be of sufficient interest to deserve separate treatment The remaining specimens from Sakrigalighat will be described in a subsequent paper

The plant-bearing beds are exposed about half-a-mile west of the ferry on the northern slope of a small hill abutting on the Ganges Surface collections were made previously by others Mr W N Edwards was the first to locate the fossiliferous beds at Sakrigalighat[2], but as far as I know none of the plant remains previously described from this locality were collected *in situ*

The plant-bearing beds are in two main zones (Pl VII, Figs 1-4) The lower zone (A), composed mainly of highly brittle shales, immediately underlies the upper hard silicified shales (B) The lower zone (A), over which the river flows during the major part of the year, is further differentiated into several bands which are, however, not clearly seen in the accompanying photographs (Pl VII, Figs 1-4) The upper zone (B), about six inches to one foot in thickness, can be traced almost horizontally along the base of the cliff

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[1] Sahni and Rao (1931), p. 184.

[2] See Sahni and Rao (1931), p. 185, footnote.

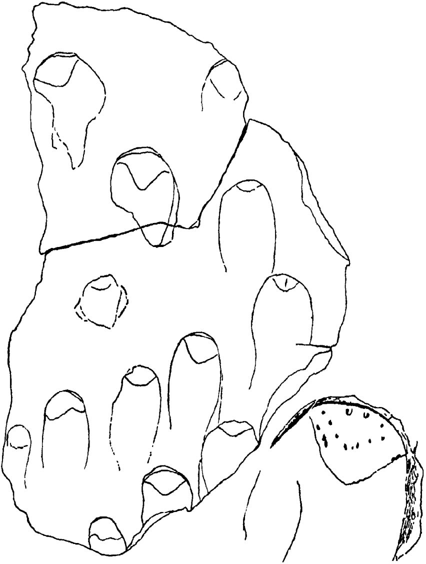

Fig.1

Text Fig. 2

TEXT-FIG 1 —*Protocyathea rajmahalense* sp nov Rough sketch of the type-specimen showing the arrangement of the leaf-cushions and scars *ca* Natural size.

TEXT-FIG 2 —*Protocyathea rajmahalense* sp nov One of the leaf-scars showing the arrangement of leaf-traces × 3

The fossils described in the present communication were found in the upper band of hard silicified shales (B), the lower zone composed of brittle shales (A), though rich in other plant remains, has not so far yielded any fossils similar to those described below

Cyatheaceous *stems* were hitherto described mainly from the Cretaceous rocks Quite recently two Upper Jurassic species from Korea were described by Ogura[3] The discovery of these fossils in the Rajmahal series, which is at present considered to be probably of Middle Jurassic age,[4] takes us further back in the geological scale, assuming, of course, that the Sakrigali beds are not higher than the rest of the Rajmahal series A careful geological study of this and other plant-bearing localities in the Rajmahal Hills from the stratigraphical point of view should help to clear up much doubt regarding the exact horizons to which the various members of this classical flora belong

2 *Description*

Protocyathea Feistmantel 1877 [5,6]

The genus *Protocyathea* created by Feistmantel is a convenient designation for all tree ferns of Cyatheaceous affinity, that are preserved either in the form of casts or impressions, and whose real affinity to any particular living genus cannot be determined owing to the absence of preserved internal structures The vascular bundles within the leaf-scars are generally preserved as a number of warts arranged in the form of arcs There is little doubt that, as at present understood, this comprehensive genus is highly artificial

The type specimen of the genus, now preserved in the Museum of the Geological Survey of India (Pl X), is a stem cast showing large spirally arranged leaf-scars with traces of a few vascular bundles within them, it was collected by H F Blanford from rocks regarded as Cretaceous in the Trichinopoly District of South India[7]

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[3] Ogura (1927), pp 352-364, Ogura (1927), pp. 364-368

[4] Sahni (1932), pp 14, 15

[5] The genus *Protocyathea* Fst, and the family Protocyatheaceæ created by Bower (1926, pp 282-292) to receive the two comparatively primitive genera *Lophosoria* and *Metaxya* have no direct relationship whatever with each other.

[6] Feistmantel (1877), p 136

[7] See below page 82.

Protocyathea rajmahalense sp nov

E 188, E 189; E 190 (unfigured), E 191[1]

(Plate VIII, Figs 5–7, Plate IX, Figs. 8–11, Text-Figs 1, 2)

Type specimen. E 188 (Plate VIII, Fig 5; Text-Fig 1).

Diagnosis *Stem impressions with large spirally arranged leaf-cushions or bases, each bearing at its upper end the rhomboid scar of a fallen leaf Cushions compactly arranged on the older parts of the stem, about* 5·0 *to* 5·5 *cm by* 1·7 *to* 2 *cm, surface wrinkled Scars roughly rhomboidal with their longer axes horizontal, about* 0·9 *to* 1·0 *cm. by* 1·4 *cm, vascular bundles few (about fourteen ?), in two curved rows, with two large median bundles at the top in the upper row (see Text-Fig.* 2) *In the younger parts of the stem the cushions are greatly reduced, the petiolar scars of adjacent leaves being almost contiguous, vascular bundles not preserved*

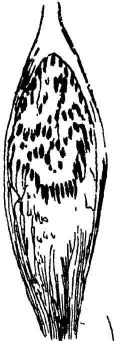
Four specimens are known of which one (E 190) is in a very bad state of preservation and is not figured They represent impressions of the younger as well as the older regions of the stem In the latter, the surface of the stem is seen covered over by spirally arranged persistent leaf-bases or cushions But due to incomplete preservation it is difficult to determine the phyllotaxy At the top of each leaf-cushion or leaf-base is seen the scar of a fallen leaf, with small marks, no doubt of vascular bundles (Pl VIII, Fig. 5; Pl IX, Fig 11, Text-Figs 1, 2). Below the scar the leaf-cushions exhibit a wrinkled appearance which is probably due to the scars of ramenta, though it may as well be due to a general shrinkage of the surface of the leaf-base. The leaf-cushions or bases are mostly elongated along the length of the stem (Pl VIII, Fig. 5, Pl, IX, Fig. 8, Text-Fig 1). This is the condition seen in specimens which probably represent the older parts of the stem In other specimens the leaf-scars have their long axes horizontal (Pl VIII, Fig 6; Pl IX, Fig 8, top half), and the scars are densely crowded, apparently with hardly any trace of the leaf-cushions between them (Pl VIII, Fig 6, *b*) This condition seems to represent the younger parts of the stem A similar compact arrangement of scars is seen in some of the living Cyatheaceæ[2] In Fig 6, on Pl. VIII, both these conditions are seen in one and the same specimen.

The arrangement of the relatively few vascular bundles within the scar is not complicated, it seems, however, that they are not all of them preserved, hence a clear description of their arrangement is impossible

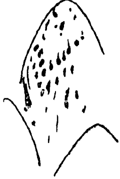
The four specimens are described separately below

[1] Numbers in this form indicate the specimens from Sakrigalighat (locality E, in Sahni and Rao, 1931).

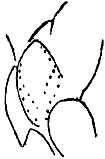
[2] Ogura (1927 *a*), Figs 35–37, 70.



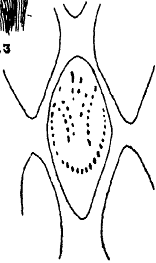
Text Fig.3



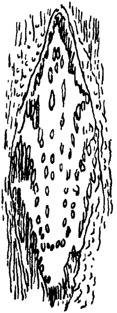
Text Fig.4



Text Fig.5



Text Fig.6



Text Fig.7

Text-Fig 3—*Protocyathea cyatheoides* (Unger) One of the scars showing the arrangement of the leaf-trace bundles (After Unger 1867, Taf 1, Fig 3)

Text-Fig. 4—*Protocyathea trichinopoliensis* Feistmantel One of the scars showing the arrangement of the leaf-trace bundles. (After Feistmantel, 1877, Pl 1, Fig 1)

Text-Fig 5—*Protocyathea cretacea* (Stenz) One of the leaf-scars showing the arrangement of the leaf-trace bundles. (After Hosius und van der Marck, 1880, Taf 43, Fig 86)

Text-Fig 6—*Protocyathea Tokunagai* Ogura One of the scars showing the arrangement of the leaf-trace bundles × 2/3 (After Ogura, 1931, Text-Fig. 1)

Text-Fig 7—*Cyathocaulis naktongensis* Ogura One of the scars showing the arrangement of the leaf-trace bundles × 4/5 (After Ogura, 1927, Text-Fig 1)

Specimen 1 (Holotype)

E 188 (Plate VIII, Fig 5; Plate IX, Figs 9–11, Text-Figs 1, 2)

This specimen shows the older part of the stem, with thirteen persistent leaf-cushions spirally arranged (Pl VIII, Fig 5, Text-Fig 1) Each cushion measures about 5 0 to 5 5 cm by 1 4 to 1 7 cm, and at the top of each can be seen the scar of a fallen leaf (Pl IX, Fig 11) The leaf-scars measure about 0 9 to 1 0 cm by 1 4 cm, and show a few small marks of vascular bundles, which unfortunately are only partly preserved (Pl IX, Fig 11, Text-Fig. 2) The best preserved and completest scar is shown in Pl IX, Fig 11 As far as can be made out, about fourteen separate and wart-like vascular bundles are seen more or less regularly arranged as follows about eight bundles are arranged in an arc in the centre of the scar, and an upper row of three or four bundles runs close to the upper margin, the two median bundles in this upper row are larger than the rest (Pl IX, Fig 11, Text-Fig 2), below, and on one side of the central row of eight bundles, is seen a group of three bundles which perhaps formed part of the lowermost arc of vascular traces that are only incompletely preserved on one side Impressions of certain elongated cells (sclerenchyma or ? tracheids) are preserved in certain parts of the stem (Pl VIII, Fig 5, Pl IX, Fig 10) A few marks of adventitious roots are also seen between the leaf-cushions, but the preservation is too poor to show the details

Specimen 2.

E 191 (Plate VIII, Figs 6, 7)

In this specimen the leaf-scars are densely crowded, apparently with hardly any trace of the leaf-cushions between them (Pl VIII, Fig. 6 *b*) Lower down, however, are seen one or two older scars with well-developed leaf-cushions somewhat similar in shape to those seen in the previous specimen (Pl. VIII, Fig 6 *a*) The "wrinkling" on the surface of these leaf-cushions is also similar It is quite possible that the specimen belongs to a younger part of the stem, where the leaf-cushions have not yet developed (*cf* Ogura, 1927 *a*, Figs 35–37, 70) Vascular bundles are, however, not preserved A few impressions, probably of adventitious roots, are present One such root is seen clearly in the side view of the specimen in Plate VIII Fig. 7 *r* The deep groove (marked *l* in this figure) which originates from one of the smaller rhomboidal scars may be the impression of an attached leaf-stalk (Pl VIII, Fig 7 *l*)

Specimen 3

E 189 (Plate IX, Fig 8)

This specimen is interesting in that it shows a gradation between the upper closely appressed scars which hardly possess any trace of cushions, and the lower scars which display well-developed leaf-cushions between them (Pl IX, Fig 8) As pointed out above, a similar differentiation in the arrangement of the leaf scars in the younger and older parts of the stem is often clearly displayed in the living Cyatheaceæ (*cf* Ogura, 1927 *a*, Figs. 35–37, 70)

Specimen 4

E 190 (Unfigured)

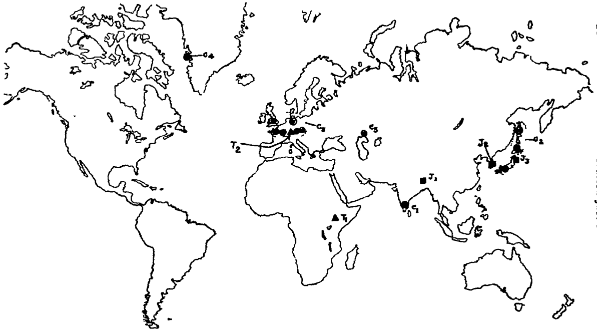
A badly preserved curved stem which shows indistinct leaf-cushions.

I have ventured to keep the above four specimens within the single species *Protocyathea rajmahalense* sp nov There can be very little doubt that Specimens 1 and 3 belong to the same species Specimen 2 at first sight appears to be somewhat different from the rest, because it shows leaf-scars which possess practically no trace of cushions But Specimen 3 displays a gradual transition from the lower scars with well-developed leaf-cushions to the upper leaf-scars with hardly any cushions As a similar differentiation in the form of the leaf-scars of the younger and older parts of the stem is also seen in the living Cyatheaceæ, I have little hesitation in considering the above specimens as belonging to the identical species.

3 *Discussion*

(*a*) *Systematic position of the Rajmahal species.*

From the above description it seems fairly clear that our fossils belong most probably to tree-ferns of Cyatheaceous affinity The large size of the leaf-cushions, the gradation between the scars of the lower and higher regions, and the arrangement of the vascular bundles, all point out—as far as mere impressions of vegetative parts can be a guide to affinity—that they are



TEXT-FIG. 8.—Map showing the Distribution of some Mesozoic and Tertiary Cyatheaceæ. (Fronds excluded, see Seward (33), pp 343, 369 for the distribution of Cyatheaceous fronds).

▲ T — Tertiary

● C — Cretaceous

■ J — Jurassic

probably related to the modern family Cyatheaceæ The characters of the fossils agree most nearly with those of the genus *Protocyathea* Fst

In his diagonsis of *Protocyathea* Feistmantel[10] mentioned the following characters as distinctive of the genus—"*Filix arborescens, caule tereti; cicatricibus ramorum (foliorum) spiraliter dispositis, nunc maximis nunc mediocribus, structura earum cicatricibus Cyathearum viventium proxima*" And our species can best be accommodated in Feistmantel's genus, within which should also be included all stem impressions or casts of Cyatheaceous affinity which show separate vascular bundles in the leaf-scar

As far as I have been able to judge from the published records, our fossils are not identical with any species of *Protocyathea* previously described They are therefore referred to a new species *Protocyathea rajmahalense*

(*b*) *A review of the genus* Protocyathea *Fst*

A detailed comparison of the Rajmahal specimens with the described species of *Protocyathea* is best carried out after a general review of the genus Four species of *Protocyathea* have hitherto been described, and the different species are distinguished primarily by the number and arrangement of the vascular bundles within the leaf-scar, and to some extent by the shape of the leaf-cushions The chief characters of the four species are briefly dealt with below For a detailed study of the individual species, see also Table I

Protocyathea cyatheoides (Unger) Feistmantel

(Text-Fig. 3, Table I)

1867 *Caulopteris cyatheoides* Unger[11]
1877 *Protocyathea Ungeri* Feistmantel[12]
1900 *Alsophilina cyatheoides* Potonié[13]
1927 *Protopteris cyatheoides* Hirmer[14]

From the Lower Cretaceous (Neocomian) of Ischl in Austria The chief characters of this species are :—Leaf-scars large and spirally disposed, tapering towards the ends, leaf-trace composed of 40 to 60 bundles, somewhat irregularly arranged, as shown in Text-Fig 3

Protocyathea cretacea (Stenzel) Ogura

(Text-Fig 5, Table I)

1880 *Protopteris punctata* Hosius und van der Marck[15]
(only figured, not described)

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[10] Feistmantel (77), p 136.

[11] Unger (67), p. 643, Pl I, Figs. 1–4; Renault (83), p 72, Stenzel (97), p 16

[12] Feistmantel (77), p. 136, Posthumus (31), p. 137.

[13] Potonié (00), p. 39.

[14] Hirmer (27), p. 641

[15] Hosius und van der Marck (80), Pl. 43, Fig 186.

1897 *Caulopteris cretacea* Stenzel [16]
1927 *Protopteris cretacea* Hirmer [17]
1931 *Protocyathea cretacea* Ogura [18]

From the Upper Cretaceous (Senonian) of Westphalia in Germany The chief characters of this species are —Leaf-scars somewhat small, spirally arranged, leaf-trace composed of about twenty-six separate bundles, regularly arranged, as shown in Text-Fig 5

Protocyathea Tokunagai Ogura

(Text-Fig 6, Table I)

1931 *Protocyathea Tokunagai* Ogura [19]

From the Upper Cretaceous (Senonian) of Japan The species is characterised by about thirteen vertical rows of spirally disposed large leaf-scars each of which shows about a hundred separate and regularly arranged bundles as shown in Text-Fig 6 The arrangement recalls *Cyathocaulis naktongensis* Ogura[20] (Text-Fig 7), a species which has been placed under a separate genus as the internal anatomy is known

Protocyathea trichinopoliensis Feistmantel

(Plate X, Text-Fig 4, Table I)

1877 *Protocyathea trichinopoliensis* Feistmantel [21]

From the Upper Creataceous (Cenomanian) of Trichinopoly in South India Prof L Rama Rao of Bangalore in a letter to me expresses the opinion, (which I may be allowed to quote), that the fossil probably " belongs to the Utatur group which forms the oldest sub-division of the Trichinopoly Cretaceous " The leaf-cushions are spirally disposed Feistmantel[22] describes the formation of a convex disc in the upper portion of the scar This disc is not well seen in the original specimen which, thanks to the kindness of the Director of the Geological Survey of India, I have been able to examine in Calcutta Apparently the leaf-scar and leaf-cushion are not clearly differentiated Each scar shows about twenty separate bundles of which nine or ten are seen arranged in a lower arc, a few bundles at the top of the scar which are seen in the type specimen, however, are indistinctly drawn in Feistmantel's figure, here reproduced as Text-Fig 4, they are somewhat

[16] Stenzel (97), p. 17.
[17] Hirmer (27), p 641
[18] Ogura (31), p 58.
[19] Ogura (31), p 58, Text-Fig 1, Pl IV
[20] Ogura (27), p 352, Text-Fig 1
[21] Feistmantel (77), p 136, Pl I, Figs. 1, 2.
[22] Feistmantel (77), p. 136.

TABLE I.

Showing the Relationship between certain Cyatheaceous Fern Stems at present included within the Genus Protocyathea

Species	Locality	Age	State of preservation	Approximate diameter of Specimen	Leaf-cushion or Scar			Leaf-trace bundles		Hairs or Scales	Roots	Further Remarks	Synonyms	More important references
					Shape	Approximate size in cm	Arrangement	Approximate number	Arrangement					
Protocyathea cyatheoides (Ung.) Fst. (Text Fig. 3)	Ischl Austria	Lower Cretaceous (Neocomian)	Cast	6·7 cm	Oblongly rhomboidal; lower end more elongate and acuminate	8·8–13 × 2·8–3·5	Spirally disposed, phyllotaxy 7/32, probably in 10 rows	46–60	Somewhat irregular, about 37 round the periphery of scar, about 9–12 towards the basal half arranged in two main arcs directed downwards, 2 median arcs in the centre directed downwards, the rest at the top arranged irregularly		Aerial roots	Unger (67) compares this with the living *Cyathea compta* and *Cyathea excelsa*	*Caulopteris cyatheoides* Unger 1867 *Protocyathea Ungeri* Feistmantel 1877 *Alsophilina cyatheoides* Potonié 1900 *Protopteris cyatheoides* Hirmer 1927	Unger (67) Schimper (69) Feistmantel (77) Stenzel (97) Potonie und Gothan (21) Hirmer (27) Ogura (31)
P. trichinopoliensis Fst. (Plate IV, Text Fig. 4)	Trichinopoly South India	? Upper Cretaceous (? Cenomanian)	Cast	10 cm	Oblongly rhomboidal, upper end obtuse, lower, more elongate and acuminate	5·5–8·3 × 2·7–2·9	Spirally disposed, 13 or 14 vertical rows of leaf scars, scars alternating	About ? 20	About 10 along the periphery of the "cushion", the rest above indistinct			Feistmantel (77) compares it with *Cyathea compta*		Feistmantel (77) Ogura (31)
P. Takenagai Ogura (Text Fig. 6)	Iwaki Japan	Upper Cretaceous (Senonian)	Cast	8–10 cm	Fusiform	6–7 × 3–3·5	Spirally disposed in 13 vertical rows, scars alternating, more closely arranged	About 100	Regular, half the number along the periphery of the scar, and the other half within this, of which 2 pairs of 10 each at the upper half curving towards the centre in an arc, and 10 in median upper half arranged in 2 rows		Marks of aerial roots between scars	Ogura (31) compares it with the Cyathea		Ogura (31)
P. cretacea (Stenzel) Ogura (Text Fig. 5)	Westphalia Germany	Upper Cretaceous (Senonian)	Cast	6 cm	Rhomboido-oval, upper part more obtuse	3 × 1·5	Spirally disposed, scars alternating	About ? 26	Regular. 2 rows of 5 or 6 each on either side running along the margin in the lower half of the scar, forming a V, others, about 10 or 12, similarly arranged within this V, and run parallel to it. the rest in the top half along the margin of scar		Marks of aerial roots	Stenzel (97) compares it with *Cyathea infera*	*Protopteris punctata* Hosius und van der Marck 1880 *Caulopteris cretacea* Stenzel 1897 *Protopteris cretacea* Hirmer 1927	Hosius und van der Marck (80) Stenzel (97) Hirmer (27) Ogura (31)
P. rajmahalense sp. nov. (Text Fig. 2)	Sakrigalighat (The Rajmahal Hills) India	? Jurassic	(a) Impression	11–12 cm (incomplete)	(a) Scars rhomboidal, cushions developed, upper part blunt and obtuse, lower tapering, leaf trace bundles within the scars	5–5·5 × 1·7–2	(a) Stem comparatively old, scars spirally disposed, number of rows of scars probably more than 14	About ? 14	(a) Regular, about 5 in the middle of the scar, arranged in the form of an arc, about 3 or 4 above this running parallel to the upper margin of scar, 3 below the middle arc of bundles lying on one side of it and close to the lower margin of scar	Scales or hairs especially on the cushion below scar	Marks of a few aerial roots between cushions	Each leaf cushion divided into an upper leaf scar and a lower delicately sculptured part. Leaf cushion not formed in the upper part of stem		
			(b) Impression	incomplete	(b) Cushions more or less obsolete	*Lower down* –4–4·2 × 1·6–1·5 *Higher up* – 0·8–1·1 × 1·1–1·3	(b) Stem comparatively young, scars spirally disposed		(b) Not preserved					

irregularly arranged in the original specimen Certain oblong grooves are present in the lower half of the leaf-cushion (Pl X) Feistmantel[23] applies the term 'stigmata' to these structures To judge from their appearance in the original specimen they are structures of a different nature from vascular bundles These structures may be compared with pneumatophores as figured by Bower in *Alsophila*[24]

(*c*) *Comparison with the other species of* Protocyathea

From a brief consideration of the different species of *Protocyathea* at present included within the form genus, it is clear that the Rajmahal species shows the closest resemblance with the South Indian species *P trichinopoliensis* Fst[25] To some extent the shape and size and the arrangement of the leaf-scars in the older parts of the stem, is similar to that in *P trichinopoliensis* Fst The general plan of distribution of the few vascular bundles in *P. trichinopoliensis* Fst is less complicated than in the other species of *Protocyathea* (*cf* Text-Fig 4 with Text-Figs 3, 5–7) On the other hand, the irregular arrangement of the vascular bundles above the lower arc of bundles in *P trichinopoliensis* Fst (Text-Fig 4) is quite different from that in the Rajmahal species, where the uppermost bundles are seen disposed quite regularly, running close to the adaxial margin (Text-Fig. 2) *P trichinopoliensis* Fst, moreover, differs from the Rajmahal species in the absence of a clearly differentiated leaf-scar on the upper part of the cushion and of corrugations on the leaf-cushions In the absence of 'stigmata' and in the presence of a smaller number of vascular bundles, our specimen shows further important differences from the Cretaceous species from South India Therefore the species is described as new

The other species of *Protocyathea* show little resemblance with *Protocyathea rajmahalense* sp nov The size and shape of the leaf-scars, and the arrangement of the numerous vascular bundles, both in *Protocyathea cyatheoides* (Unger)[26] and *Protocyathea Tokunagai* Ogura,[27] are totally different (see Text-Figs 3, 6) As regards *P cretacea* (Stenz),[28] although it comes nearer to the Indian species in the size of the scars and in the smaller number of vascular bundles, the arrangement of the bundles is different

[23] Feistmantel (77), pp. 136, 137 , Pl I, Figs 1, 2

[24] Bower (23), p. 203, Fig 193

[25] Feistmantel (77), pp 136, 137 , Pl I, Figs. 1, 2

[26] Unger (67), Pl I, Figs 1–4

[27] Ogura (31), Pl IV, Text-Fig. 1.

[28] Hosius und van der Marck (80), Pl. 43, Fig. 186

(*d*) *Geological and geographical distribution of the Cyatheaceæ*

General.—For a clear understanding of the geological and geographical distribution of the Cyatheaceæ, records of fern fronds as well as stem remains have to be briefly considered. The distribution of fern fronds believed to be of Cyatheaceous affinity has already been treated by Seward and others,[29] and there is little necessity to go over that difficult ground again. Our attention is confined mainly to the stem remains preserved in the form of petrifactions, casts or impressions, which may be reasonably referred to the Cyatheaceæ (see Table II). Before entering into a discussion regarding their distribution, geological and geographical, the value of each genus as evidence of Cyatheaceous affinity should be considered. Posthumus[30] and Bancroft[31] have recently made similar attempts.

Petrifactions.—The most important and widely distributed stem genus referred to this group is *Protopteris*, which includes both petrifactions and casts.[32] The probable Cyatheaceous affinities of this genus can be recognised by its leaf-trace with inwardly curved ends and plicate margin. The two east Asiatic species, *Cibotiocaulis Tateiwæ* Ogura[33] and *Cibotium iwatense* Ogura,[34] resemble the living genus *Cibotium* in the mode of departure of the leaf-traces and in the arrangement of the vascular bundles in the petiolar base. *Caulopteris arborescens* Stenzel[35] and *Caulopteris Brownii* Renault[36] show to a certain extent stelar similarity with the modern Cyatheaceæ. But certain features in which the two above-mentioned species differ from the living Cyatheaceæ were already pointed out by Bancroft[37] and Rao.[38] The stem anatomy of *Cyathocaulis naktongensis* Ogura[39] can best be compared, according to Ogura, with that of the living species *Dicksonia antarctica*. *Dendropteridium cyatheoides* Bancroft[40] shows an undoubted polycyclic

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[29] Seward (33), pp 343, 369, Seward (10), p. 367, Halle (13), pp. 17, 94, Hirmer (27), p 637, Thomas (11), p 387, Potonié und Gothan (21), Schenk in Zittel (90), pp 92–95.

[30] Posthumus (31).

[31] Bancroft (32), p 249.

[32] Seward (10), pp. 370–375, see also for further references.

[33] Ogura (27), pp 364–368, Text-Figs. 10, 11, Pl III, Figs 13-15; Pl. VIII, Figs 43–49

[34] Ogura (33), p 748, Text-Figs. 1, 2, Pl. II, Figs 1–4.

[35] Stenzel (97), p 10, Pls. I, II, III, Figs 16–19.

[36] Renault (83), p 73, Pl VIII, Fig 10, Rao (34), pp. 221-225, Pl XXXIII, Figs 3–6

[37] Bancroft (32), p 349

[38] Rao (34), p 221

[39] Ogura (27), p 351, Text-Figs 1–9; Pl II, Figs. 1–6, Pl. III, Figs. 7–12; Pls IV–VI.

[40] Bancroft (32), p. 241; Text-Figs 1, 2, Pls. IX, X.

TABLE II.

Table showing the Geological and Geographical Distribution of some Mesozoic and Tertiary Cyatheaceæ (Fronds excluded). For the distribution of Cyatheaceous fronds, see Seward (33), pp. 343, 369, and the literature cited therein

	Jurassic		Cretaceous		Tertiary		ASIA					AFRICA	N. W. AND CENTRAL EUROPE							BR. ISLES	ARCTIC	Further Remarks
	Lower	Upper	Lower	Upper	Early	Late	Rajmahal Hills	Trichinopoly	Siberia	Japan	Korea	E. Africa	Austria	Galicia	Silesia	Bohemia	Westphalia	Saxony	France	England	Greenland	
							J_1	C_1	C_2	C_2	J_2	T_1	C_3	C_3	C_3	C_3	C_3	C_3	C_3	C_3	C_4	→ Ref. to Map
1 *Protopteris punctata* Sternb.			●	●											×	×	×	×		×	×	
2 *P. Witteana* Schenk			●														×			×		
3 *P. fibrosa* Stenzel				●											×							Turonian
4 *P. Buvignieri* Brong.			●																×			
5 *P. Wohlgemuthi* Fliche				●															×			Albian
6 *P. Dupleryana* Saporta				●															×			Albian
7 *Protopteris confluens* Stenzel									×									×				Probably root of *Rhizodendron oppeliense* Göpp.
8 *Cibotiocaulis Tateiwae* Ogura		●									×											
9 *Cibotium iwatense* Ogura				●						×												Senonian
10 *Oncopteris Nettvalli* Dorm.				●												×						Cenomanian
11 *O. Kauniciana* Dorm.				●												×						Perucer
12 *O. Laubei* (Engelh.) Ogura					?●											T_3 (Bohemia)						Exact horizon unknown
13 *O. Cordai* Vel. et Vin.				●												×						
14 *Protocyathea cyatheoides* (Ung.) Fel.			●										×									Neocomian
15 *P. trichinopoliensis* Feist				?●				×														Exact horizon unknown
16 *P. Tokunagai* Ogura				●						×												Senonian
17 *P. cretacea* (Stenzel) Ogura				●													×					Senonian
18 *P. rajmahalense* sp. nov.		?●					×															Exact horizon unknown
19 *Rhizodendron oppeliense* Göpp.														×	×			×				Senonian (Galicia) Turonian (Silesia)
20 *Caulopteris ? sch...* Stenzel				?●														×				
21 *Caulopteris Hermani* Ren.				?●																×		
22 *Dendropteridium Cyatheoides* Bancroft						●						×										
23 *Cyatheocaulis naktongensis* Ogura		●	●							×	×											
24 *Cyatheorachis Fujiiana* Ogura				●						×												

structure of Cyatheaceous type The genus *Cyathorachis Fujiiana* Ogura[41] is a well preserved piece of rachis showing numerous bundles arranged as in some modern Cyatheaceæ *Rhizodendron oppoliense* Göpp.[42] on the other hand, is a species of doubtful affinity which has been included under the Cyatheaceæ by certain authors It shows fibrous bundles in the cortex and pith with sclerenchymatous tissue outside the main stele. The leaf-trace has four or more strands

Impressions—Among the casts and impressions of Cyatheaceous affinity *Oncopteris*[43] and *Protocyathea*[44] are the two important genera *Protopteris*, as mentioned above, is also known as casts The internal anatomy of the species included in the first two genera is at present unknown, and till their internal structure is known they cannot be removed from the present position of uncertain affinity to a more stable footing But their affinities are no doubt more with the Cyatheaceæ than with any other group of ferns The genus *Oncopteris* shows, besides a ring of separate wart-like bundles, two <-shaped or C-shaped bundles at the top of the scar A similar arrangement of the vascular bundles in the leaf-base is also noticed in some of the living Dicksonieæ The affinities of *Protocyathea* with the living Cyatheaceæ have already been considered elsewhere in detail

From the above brief discussion it would appear that as far as their anatomy is concerned, the Cyatheaceæ have descended from their Mesozoic ancestors with but little modification

Table II is intended to illustrate the distribution in space and time of such fossil stems as may be reasonably regarded, on data at present available, as members of the Cyatheaceæ

The geographical distribution of the living Cyatheaceæ has been ably dealt with by Diels[45] Their distribution in a broad belt throughout the tropics and sub-tropics of the Old and the New Worlds forms a striking contrast to their distribution in the past

According to Seward[46] "We have as yet no satisfactory evidence of the existence of the Cyatheaceæ in Palæozoic flora"

[41] Ogura (27), p 368, Text-Figs 12, 13, Pl. VIII, Figs. 50-54

[42] Göppert (65), p. 397, Stenzel (86), p 5, Pl I, Figs 1, 3, 5-12, Pl II, Pl III, Figs 20-29, Rao (34), pp 225, 226.

[43] Krejci (53); Feistmantel (72), Velenovský (88), Potonié (90), Frič und Bayer (01), Seward (10), Pelourde (11); (14); Engelhardt (81); Stenzel (97); Hirmer (27), Ogura (31); Velenovský and Viniklář (29).

[44] See Table I for full references

[45] Diels (02), pp 117, 122, 124-138.

[46] Seward (10), p. 366.

Rhætic.—It is not till the Rhætic period is reached that we find anything like definite evidence of this family of ferns, and in these rocks, too, they have so far been found only in the form of leaf impressions[47] The only Rhætic record so far known is from Tonkin.

Jurassic—During the Jurassic, however, the Cyatheaceæ had a world-wide distribution We have several undoubted records of Cyatheaceous ferns (both stem remains and fronds) Of petrified *stems*, the earliest reliable evidence so far available was from the Upper Jurassic, namely, *Cibotiocaulis Tateiwæ* Ogura[48] from Korea, and *Cyathocaulis naktongensis* Ogura[49] from Japan The discovery of *Protocyathea rajmahalense* sp nov. from the Rajmahal series, which is at present believed to be of Middle Jurassic age,[50] therefore takes us further back in the geological scale (see Table II) In the Jurassic rocks fern fronds are more commonly found than stem remains (*Coniopteris hymenophylloides* (Brong) and *Eboracia lobifolia* (Phill.)[51] were well represented in the vegetation of this period Another fern possibly belonging to the same family was *Stachypteris*[52]

Cretaceous—The Cretaceous records are mainly confined to the stem remains, the largest number being found in the Upper Cretaceous (see Table II) The fronds which were abundantly represented in the Jurassic are singularly rare in these rocks But there is enough evidence to show (from the stem remains so far known), that the Cyatheaceæ were more or less well represented during this period as well (see Table II), though probably not to such a great extent as in the Jurassic *Protopteris punctata* Stern described by Heer[53] from the Cretaceous of Greenland, establishes the extreme northerly distribution of the group *Protocyathea trichinopoliensis* Est from the Cretaceous rocks of South India, also shows the wide range of the family during that period

Tertiary—There is great scarcity of Cyatheaceous records of any type after the Cretaceous Except for two species of stems, *Oncopteris Laubeji* (Engelh) probably from the early Tertiary of Bohemia,[54] and *Dendropteridium cyatheoides* Banc from the late Tertiary of E Africa,[55] there is no evidence of a reliable nature

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[47] Zeiller (03), p 36, Pl. IV, Fig. 1, Halle (13), p 94, Seward (33), pp. 343, 350

[48] Ogura (27), p 364

Ogura (27), p 351

Sahni (32), pp 14, 15.

See Halle (13), for full reference, pp 19–21 *Coniopteris hymenophylloides*, pp 16–17 *Eboracia lobifolia*, Hirmer (27), pp 637–639

Thomas (12), Seward (33), p. 350.

Heer (82), Pl. XLVII

Engelhardt (81), p 284, Taf 1, Figs. 1–4

Bancroft (32), p. 241

Conclusion.—Thus, if we consider the records of stem remains and frond impressions collectively as evidence for the existence of Cyatheaceous ferns, it can safely be said that the group was abundantly represented in the vegetation of the Jurassic and Cretaceous periods, and enjoyed an almost cosmopolitan existence By the end of the Cretaceous they had already started disappearing from the northern regions, and during the period that followed, in company with other groups of ferns such as the Gleicheniaceæ and the Marattiaceæ, they became confined to their present restricted distribution within the tropics and south temperate zone

(e) *Geological age of the Sakrigalighat beds*

A definite opinion on the geological age of the beds cannot be ventured at this stage It will, however, be discussed after the other specimens from this locality are examined and described But it may be mentioned that *Protocyathea* is a genus previously recorded only from the Cretaceous rocks

4 *Summary*

1 *Protocyathea rajmahalense* sp nov is described from certain beds at Sakrigalighat, in Behar

2 The earliest recorded species of Cyatheaceous *stems* are from the Upper Jurassic of Korea The discovery of the Indian species takes us further back in the geological scale, because the Rajmahal series is probably not so young as the Upper Jurassic, unless of course, the Sakrigali beds are higher than the rest of the Rajmahal series, a question which deserves the attention of geologists

3 The affinities of the Rajmahal species with the other species of *Protocyathea* are discussed The closest resemblance is with *Protocyathea trichinopoliensis* Fst from the Cretaceous of South India Due to certain important differences from the latter, the Rajmahal form is described as a new species

4 The distribution of the Cyatheaceæ, both living and fossil, is briefly discussed.

5 *Acknowledgment*

My grateful thanks are due to Professor B Sahni, F R S, for his invaluable and most generous help and criticisms throughout the course of this work. For his personal inspiration, which has been a constant source of encouragement, and for all that my association with him for the last few years has meant for me, which is much more than I can mention here, I wish to express my deepest gratitude.

To the Director, Geological Survey of India, I am indebted for permission to examine the type specimen of *Protocyathea trichinopoliensis* at Calcutta, and to reproduce a photograph of it (Pl X)

I am also indebted to Prof L Rama Rao of the Department of Geology, Central College, Bangalore, for valuable information regarding the probable stage of the Trichinopoly Cretaceous to which *P. trichinopoliensis* Fst. belongs.

My thanks are also due to the authorities of the Lucknow University for the award of a Research Fellowship during the course of this work

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EXPLANATION OF PLATES

All figures are untouched photographs. With the exception of the original of Plate X, all the figured specimens come from Sakrigalighat, and are preserved in the Department of Botany, Lucknow University.

PLATE VII

FIG. 1.—Photograph showing the band of hard silicified shale (Zone B) which runs along the base of the cliff, Sakrigalighat. All the specimens of *Protocyathea rajmahalense* here described were collected from this stratum.

FIG. 2.—A view of the same zone (Zone B) in the month of October when the river is in floods. The soft brittle strata (Zone A) are submerged.

FIG. 3.—A view of the soft strata (Zone A) from the north-west. The bed of hard silicified shales (Zone B) can be seen in the background overlying the soft shales.

FIG. 4.—Photograph showing the soft shales (Zone A) dipping north into the river. A view from the south-east, when the water has receded. The man is seen standing at the spot which yielded the major part of the collections from this zone (to be described in a subsequent paper). The hard band is seen higher up at B, also dipping north.

PLATE VIII

FIG. 5.—*Protocyathea rajmahalense* sp. nov., showing the leaf-cushions and scars × 5/6. Specimen 1 (E 188). *a*, *b*, two of the leaf-cushions magnified in Pl. IX, Figs. 11 and 9 respectively.

FIG. 6.—*Protocyathea rajmahalense* sp. nov., showing two types of leaf-scars *a*, scars with well-developed leaf-cushions, *b* scars with more or less undeveloped leaf-cushions. Natural size. Specimen 2 (E 191).

FIG. 7.—*Protocyathea rajmahalense* sp. nov. A side view of Specimen 2 (E 191), figured in Plate VIII Fig. 6, showing on the left an adventitious root (*r*), and on the right a leaf-stalk (*l*). Natural size.

PLATE IX

FIG. 8.—*Protocyathea rajmahalense* sp. nov. Specimen 3 (E 189). Slightly reduced.

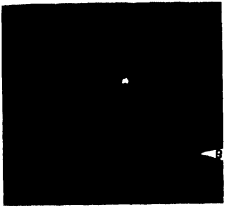
FIG. 9.—*Protocyathea rajmahalense* sp. nov. One of the leaf-scars marked (*b*) in Pl. VIII, Fig. 5, enlarged, showing impressions of scales or hairs × 2½.

FIG. 10.—*Protocyathea rajmahalense* sp. nov., showing impressions of sclerenchyma or tracheids × 4.

FIG. 11.—*Protocyathea rajmahalense* sp. nov. One of the leaf-cushions marked (*a*) in Pl. VIII, Fig. 5, enlarged, showing the leaf-trace bundles and impressions of scales or hairs below the leaf-scar × 3.

PLATE X

FIG. 12.—*Protocyathea trichinopoliensis* Fst. The type specimen (from the Cretaceous of S. India) preserved in the museum of the Geological Survey of India. From a photograph supplied by the Geological Survey of India. Natural size.



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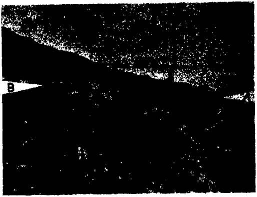

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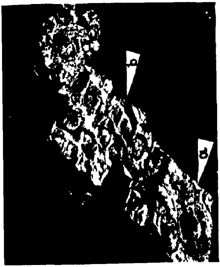

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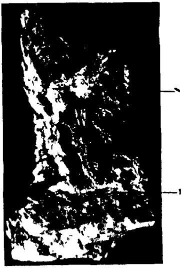

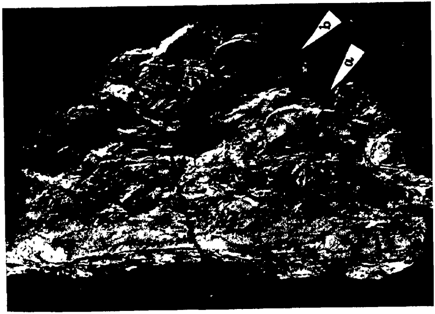

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STUDIES IN THE PHYSICAL AND CHEMICAL PROPERTIES OF SOME SUGARCANE SOILS.

By A L Sundar Rao, B Sc (Hons)

(*Allahabad*)

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Although it is not easy to find the cause which accounts for the fact, it is well known that the growth of sugarcane in many places becomes poorer year after year Though the cultivation operations improve the physical condition of the soil and increase the availability of plant nutrients, there is a limit however to the benefit which can thus be obtained In the middle of the last century, Reynoso[1] working on certain sugarcane soils, finds that the most robust canes are grown in calcareous soils and that these also afford juices rich in sugar From that time many investigators have worked on this problem Notable among these being Harrison[2] working on British Guinea soils, Crawley[3] on Cuban soils and Burgess and Kelley[4] on Hawaiian soils But none of these workers seem to have tried to co-ordinate and find out the cause of this deterioration of the soils and of the presence of poorly grown canes Isaburo Wado and Sunao Ato[5] tried to co-ordinate the results of analysis of some of the robust and poorly grown canes and some of the "fertile" and "infertile" soils supplied to them by the Ensuike Sugar Manufacturing Co, but their results do not seem to be conclusive

The chemical changes that proceed in a well-cultivated soil are essentially of the nature of oxidation Hence it appears quite possible that if the changes can be accelerated by certain chemical treatments, better plant growth and greater increase in yield may be expected During recent years there has been an increasing evidence to show that many of the elements which have been hitherto regarded as "unessential", exercise marked influence on the plant growth Subramanyan and collaborators[6] have shown in a series of papers that the organic matter either belonging to the soil or that which is added as manure undergoes decomposition yielding mineral nutrients in available form They have also shown that the decomposition which is rather slow under natural conditions can be considerably hastened by the addition of mild oxidising agents resulting in the larger release of plant nutrients and larger yield of crop

According to Leibig[7] the productivity of a soil is not however so much governed by the combined effect of all controlling factors as by the influence of one decisive feature. These trace elements may effect the availability of soil nutrient reserves or when applied with ordinary chemical fertilisers may increase their effect—even rendering them of benefit where they normally fail. Among the various workers who have contributed to this line of research mention must be made of Bertrand and co-workers,[8] Warrington,[9] Somer and Hass[10] and Reid who have shown that minute quantities of F, I, Zn, Al, Mn and B are essential to the normal growth of plant. The great importance of traces of Mn for the plant has been demonstrated by McHargue, McLean, Kelley and Gerrestsen.[11] Kelley while studying the Hawaiian soils, observed the presence of large quantities of Mn and Ti while Gerrestsen believes that Mn intensifies photosynthesis by accelerating the oxidation processes connected with the photochemical reactions in the leaf, shortage of Mn resulting in a retarded carbon dioxide assimilation. The occurrence of Mo and V in nature has been well studied by Muelen,[12] Dingwall,[13] Horner[14] and others. These investigators have observed that applications of Mo will increase at times the growth of azotobacter cultures two- or three-fold.

Recently, Dhar and his collaborators[15] investigating the application of molasses to the soil and the consequent photonitrification, observe that in tropical soils the fixation of atmospheric nitrogen by the addition of energy-rich compounds is photochemical and catalytic, and that compounds of Mn, Zn and traces of Ti greatly facilitate the oxidation reactions occurring in the soil.

In connection with his recent experiments on the utilisation of molasses as fertiliser, the author had occasion to investigate the physical and chemical characteristics of some typical soils from cane-growing areas. It is proposed here to give the results of the investigation which mainly deal with fertile and infertile samples from the same locality. After years of cultivation and manurial treatment it was found that in the same locality some soils were unproductive for sugarcane cultivation while the others responded well to manurial treatments, as indicated by the return in the quantity as well as the quality of the cane. On this basis the soils (0 1′ depth) were kindly supplied to the author by Mr. S. S. Patrudu, Superintendent of the Agricultural Research Station, Anakapalli, as representing "fertile" and "infertile" fields in adjacent blocks.

Physical Studies.—The soil-water relationships are largely dependent upon the textural composition of the soil. The mechanical composition as a method of expressing the texture of soils has been generally recognised. But in the ordinary methods the dispersion effected seems to be inadequate to separate the soil colloids from the mineral particles.

Samples from a fertile and infertile zone are analysed for a number of physical properties, including a study of the spectra emitted under suitable conditions by these soils. The samples (from the fertile and infertile regions obtained from a sugarcane field near Vizagapatam) contained the following main fractions:—

Clay (0·002 mm & below) 15·12 %
Silt (0·02 to 0·002 mm) 6·15 %
F Sand (0·2 to 0·02 mm) 44·12 %
C Sand (2·0 mm to 0·2 mm) 33·10 %

These soils occupy a large proportion of the cultivated and uncultivated areas of the tract. The absorptive capacities of the soils were next studied in squat form weighing bottles. About 10 gm of the sample is taken in the weighing bottle and exposed to sulphuric acid-water mixtures in vacuum desiccators,[16] which were kept in a thermostat at 30° C. Constancy of weight was attained after a period of forty-eight hours. But they are usually exposed for not less than three days and the moisture content determined in a hot-air oven at 105° C. The results obtained for duplicate samples from the fertile and infertile regions are given below for the relative humidities at which the experiment was done.

TABLE I

Sample	Rel Hum 20 %	40 %	60 %	80 %	100 %
Fertile 1	2·43	1·04	5·73	7·04	9·98
2	2·31	4·06	5·80	7·05	10·12
Infertile 1	0·52	1·63	2·21	3·04	5·13
2	0·56	1·68	2·27	3·00	5·18

(For the hygroscopic moisture at 100 % R H water was used in the desiccator instead of sulphuric acid.)

It is interesting to note that though the mechanical composition of the soils was practically the same for the two fields yet the powers of absorption of water varied considerably and it is here that we can seek for an explanation for the difference in fertility of the two fields.

The absorption of water vapour by the soils when exposed to sulphuric acid of 3·3 per cent strength at 28°·5 C giving a relative humidity of

98 per cent was studied over a period of 50 days in order to see whether these differences in the absorptive capacities persist The results of this experiment are given in Table II below

TABLE II

Moisture Content at Different Periods

Time in days	0	5	10	15	20	25	30	35	40	45	50
Sample 1 .	4·2	9·12	10·5	11·4	11·8	12·0	13·1	12·1	12·2	12·2	12·2
Sample 2 . .	1·4	4·2	5·3	5·8	6·2	6·4	6·5	6·6	6·6	6·6	6·6

Sample 1 is from a fertile field and the sample 2 is from the infertile area Duplicates agreed well, hence a mean value only is given above

The absorption is very rapid at first and then the rate diminishes The rate of absorption follows an exponential relationship with time of the type

$$R = k\,(1 - ae^{-kt})$$

The equation when applied to the absorption of moisture by the soil samples given above becomes

$$R = 12{\cdot}2\,(1 - 0{\cdot}65 \times 10^{-0{\cdot}08t}) \text{ for sample 1 and}$$

$$R = 6{\cdot}7\,(1 - 0{\cdot}79 \times 10^{-0{\cdot}07t}) \text{ for sample 2, where}$$

R is the moisture content in time t days

It is clear from the above that the higher absorptive capacities displayed by the samples from the fertile field might be due to the presence of higher amount of colloidal in these samples[17]

A determination of the colloidal matter present in the soil samples was made using the method due to G J. Bouyoucos[18] known commonly as the hydrometer method The duplicate samples from the two fields gave the following values at the laboratory temperature

Fertile . (Sample 1) 21·12% colloids
(Sample 2) 20·03% „
Infertile . (Sample 1) 12·21% „
(Sample 2) 10·13% „

The above values confirm the observations made earlier that the differences in the absorptive capacities might be due to the different amounts of colloids present in the samples

The Chemical Analysis of the above samples was done by the methods of the A O A C. It is surprising to note that with the exception of Lime the major constituents did not vary in the two blocks

	Fertile block	Infertile block
Insolubles	74·12	83·17
Iron and Alumina	6 73	7 42
Lime as CaO	12·10	6·52
MgO	1 52	1 56
Na_2O	0 21	0 27
K_2O	0·64	0 55
P_2O_5	0 09	0 07

Organic carbon and total nitrogen[19] in the samples was found to be as follows

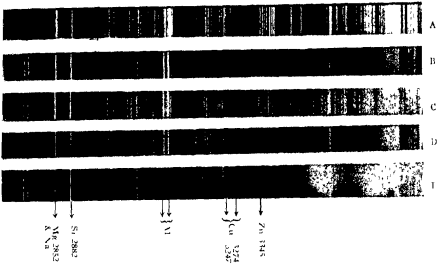
	Fertile	Infertile
Organic Carbon	1·20	1 05
Total Nitrogen	0 0475	0 0398

The above values do not conclusively show any great differences in the major constituents of the soils including the total nitrogen and organic carbon, for the fertile and infertile blocks, at least as much as to be able to account for the observed differences in the absorption towards water The experiments conducted by the author show beyond doubt that these differences in the powers of absorption are due to the differences in the colloidal content In this connection attention may be drawn to the views of F J. Alwaye,[30] P L Gile[31] and their co-workers "The colloidal material of the soils", according to Emil Troug[32], "is usually largely mineral and rarely is 10 per cent or more of it organic"

For reasons stated above a search for the mineral constituents including the trace elements was made The work reported here is of a preliminary nature, as far as the section on the spectrographic analysis is concerned, which was mainly undertaken with a view to standardise the technique employed in the analysis of soils Concentrations of the trace elements are usually so minute that their detection and estimation would require profound study of methods followed by laborious research in large quantities of the material

Spectrographic investigations of trace elements avoid these difficulties and the process of obtaining an ultimate mineral analysis of a soil becomes very simple The spectrograph can present successive stages of a profile on a single plate revealing at a glance variations in the quantity of an element A comparison of the intensities of the lines in the various spectra leads to fairly reliable results The author has therefore photographed the arc spectra of the soil samples and this preliminary investigation is mainly intended to finding all the metallic elements contained in the soils without allowing even the rare ones to escape detection For this purpose, soils previously prepared according to the official method and reduced to fine powder were used in a carbon arc, using for the purpose hollowed out carbon electrodes filled with the samples and a direct current of five amperes A slightly different form of carbon arc which was found to be specially serviceable in obtaining the spectra of metals having low boiling points was used In this the upper carbon is surrounded with a water-box through which there is kept a constant flow of cold water which prevented the temperature of the electrode from becoming too high The spectra were photographed with a Hilger quartz spectrograph and standard spectra were impressed on each plate using for the purpose samples made for pure metals and chlorides of metals The carbon electrodes used in these experiments were of the H S brand purity supplied by Adam Hilger In all cases they were mounted vertically and were brought together with a gap of about 2 mm and the arc was struck by drawing a third carbon electrode of the same kind across the gap and the current was maintained constant for all the exposures

The spectra are reproduced in Plate XI in which ' A ' is the spectrum obtained with the mixture containing Na, K, Ca, Mg, Cu, Fe, Si, Al, and Ti, Mn, Zn, V in suitable ratio ' B ' and ' C ' are spectra of fertile soils and ' D ' and ' E ' for the infertile samples for the same locality The minerals which could be indubitably detected and identified from these are Na, K, Cu, Mg, Ca, Al, Si, and Fe and the trace elements Zn, Ti, Mn and B while the presence of Be is suspected By comparing the spectra of these soil samples with those of a series of suitable ratio powders of known composition attempts have been made to determine the proportion of the minor constituents By this method, the Mn content of the majority of the fertile soils was found to range from 0·04 to 0·15 while the value of Zn ranged from 0·03 to 0 06 While the problem is evidently more complicated than would at first sight appear, there seems to be nonetheless a connection between Zn, Mn and Ti content and fertility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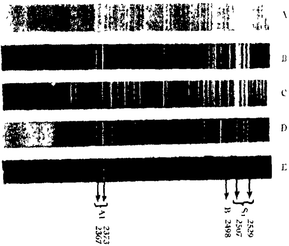
Mg 2852 & Na
Si 2882
Al
Cu 3274 3247
Zn 3345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Valuable information might be obtained by the spectroscopic examination of soils and the ashes, roots and stems and leaves of plants that grow in these soils supplemented by the chemical estimation of the trace elements. Further experiments in this direction are in progress and the author proposes to deal with these in another communication

Summary

A detailed study of the physical and chemical properties of some fertile and infertile soils from sugarcane-growing areas has been carried out The study involves the determination of the colloid content, chemical composition and spectroscopic examination for the minor constituents Although there has been no significant difference in soil composition, attention is drawn to the role of trace elements Zn and Ti in plant nutrition Arc spectra of these soil samples have been photographed and by comparing these spectra with those of a series of suitable ratio powders of known composition attempts are made to determine the proportion of the trace elements

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ON THE NATURE AND IDENTIFICATION OF SOME ROUNDISH BODIES FOUND EITHER FREE OR AS ENDOGLOBULAR PARASITES IN THE BLOOD OF *CALOTES VERSICOLOR* DAUD. SUBSPECIES *MAJOR* BLYTH.

By Prof Col I Froilano de Mello
AND
Caetano Corrêa de Meyrelles
Medical College, Nova Goa

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AMONG numerous specimens of *Calotes versicolor* subsp *major*, one of them showed us some minute, roundish, curious parasites which will be described in this note In living condition, in hanging drop preparations, they appear as circular bodies, with refringent greenish protoplasm, surrounded by a rather strong membrane and provided to a certain extent with a kind of movement which seems brownian The red globule has sometimes in its interior 2 or 3 of these bodies, but does not show any alteration Similar bodies are also found free and some of them, either free or endoglobular, have a small bud attached to the mother-cell, as it happens in yeasts

Stained by Leishmann's solution or by May-Grunwald-Giemsa, these bodies appear under various morphological aspects, figured in our coloured plate and which can be described in the following way

1 Small round chromatic dot, of anaplasmoid nature (Pl XII, Fig 2)

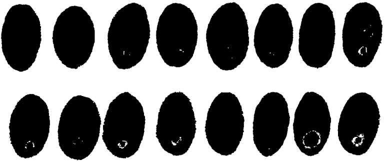
2 Small roundish body surrounded by a more or less strong membrane, taking a chromatic stain, and possessing a central nuclear granule, more or less developed (Pl XII, Figs 1, 3, 4)

- (*a*) the membrane may have two or three chromatic granules, attached to it, moreover the central nucleus (Pl XII, Fig 8),
- (*b*) the body may be devoid of any granule, resembling a mere vacuole, surrounded by the membrane (Pl XII, Figs 11, 12)
- (*c*) the central granule may be located on the periphery (Pl XII, Fig 10) and show a kind of budding (Pl XII, Figs 15, 16)

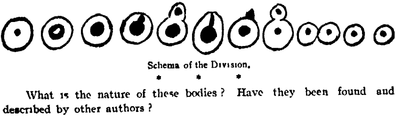
3 In all figures described under alinea 2 the interior of the corpuscle or its protoplasm was colourless. We have now figures where the protoplasm is stained blue or grey blue, often surrounded by a white circular halo

(Pl XII, Fig 13) without any granule at all (Pl XII, Fig 5), with a central chromatic granule (Fig 13) or the nuclear mass more or less peripheric (Figs 6, 7) It is not rare to find globules as figured in our Fig 9, where it seems that the parasite is almost to penetrate in the red cell The general form is circular, but often, specially when there is an appearance of budding, the form may be elliptic, elongated

Some blood smears were stained by iron-hæmotoxylin of Heidenhain after wet fixation by Schaudinn's sublimate and Bouin The general structure is the same as that found in Romanowsky's stain either anaplasmoid, or of a corpuscle with a more or less conspicuous membrane, surrounded or not by a halo and possessing in its interior, vacuolated or with a slight trace of protoplasm, a chromatic granule more or less developed This chromatic granule which acts as nucleus may sometimes show the appearance of a ring



What becomes more evident by iron-hæmatoxylin staining is the process of division of this organism The nucleus constituted by a small minute granule is enlarged and takes a ring form Further on it becomes compact and gives origin to a small bud which makes a kind of protrusion to the exterior One part of the membrane surrounds the nuclear bud and in subsequent stages the cytodieresis occur



Schema of the Division.

* * *

What is the nature of these bodies? Have they been found and described by other authors?

Consulting the literature at our disposal we see in Dutton, Todd and Tobey[1] their Fig 55 of Plate XXV labelled as "the unidentified parasite of snake-round form" and Figs 106, 108, 110, 111, 114 and perhaps 104 of the Plate XXIX, all these labelled as *Cytamœba*, which seem to us of the same nature as our actual parasite Dutton and co-workers classified them as *Cytamœba*

This name was employed by Dahlewsky (1890) as syn of ***Plasmodium*** Labbé (1894) gave the name *Cytamœba bacterifera* for some peculiar bodies in the red cells of ***Rana esculenta*** which have been named ***Bacillus krusei*** by Laveran in 1899 Having come across with the so-called *B krusei* some years ago, the senior author can assure that their nodulo-filamentar structure has nothing in common with the structure which we have described in our parasite

Wenyon, in his *Protozoology* (pp 1050-51), assembles under the same title of *Cytamœba*, in the work of Dutton and allia, both the corpuscles which we have indicated above as others, associated with some rods of crystalline nature (Dutton and allia, Plate XXIV, Figs 95–98), which, described by these authors as "an unidentified parasite", were included by França in his genus *Toddia*, sp *Toddia bufonis* (1910)

More recently Schwetz in Belgian Congo has described the ***Bacillus krusei***[2] as "organismes intracellulaires, arrondis, tantôt granuleux tantôt presque homogènes et tantôt ayant l'aspect d'un amas de minuscules bacilles"

They were found in ***Rana albilabris***, ***oxyrhynchus*** and ***occipitalis*** and in ***Bufo regularis*** The author did not find the amœboid movements seen by other authors He states that these parasites have been described by numerous authors under the names ***Bacillus krusei*** Laveran, *Cytamœba bacterifera* Labbé and *Toddia bufonis* França

Reviewing these parasites of frogs we believe

(*a*) that the so-called ***Bacillus krusei*** Lav of frogs is easily recognisable by its nodulo-filamentous contents and that *Cytamœba bacterifera* is a syn of ***B krusei***,

(*b*) that those parasites (?) which were associated with some crystals and were described by Dutton, Todd and Tobey as "an unidentified parasite", belong to so-called *Toddia* França whose nature and systematic position remains yet doubtful,

(*c*) that the so-called *Cytamœba* of Dutton, Todd and Tobey are of the same nature as the parasites we are studying now

In 1915 we find a paper by Annie Porter[3] where some organisms figured by the author in her Text-Figs 8, 9 and 10, belonging to the blood of cold-blooded vertebrates such as snakes and frogs, seem to us to belong to the same kind of organisms. Annie Porter identified them to *Anaplasma*, but we are very doubtful on such identification, as at that time much controversy reigned over the nature of *Anaplasma*, some authors as Dias and Aragaõ[4] denying their protozoan nature. It seems that Porter included among those bodies various kinds of organisms and perhaps the mistake on the recognition of their differentiation came just because she considered that the structure was the same "whatever was the host from which they were obtained—man, cattle, mice, birds, reptiles, amphibia or fish." Our opinion is based on the fact that at the side of "small, uniform, usually spheric masses, that stained intensely with chromatic stain, that is, they were basophilic" were observed other corpuscles with a somewhat less densely staining portion of cytoplasm, surrounding the chromatinic bodies. Indeed the author claims that "no marked exterior limit to such an area or halo could be found and the staining appeared to be merely an idiosyncrasy of that portion of the host cell." Whatever be the nature of those bodies—some of them, the so-called uniformly basophilic, perhaps *Anaplasma*, perhaps reliquats of cell nuclei, or *anaplasmoid*, the others with surrounding cytoplasm probably of the same rank as the bodies we are describing now—what is interesting to note in the description of Porter is the process of multiplication. "near one point of the periphery of the nucleus of the red cell, a small bud appears. This tiny projection increases in size and gradually becomes somewhat spherical. The bud thus formed is extended and passes into the cytoplasm as a small spherical body." She described also a multiple budding, "the result being a small rosette of Anaplasmata in the cytoplasm of the host cell."

It will not be devoid of interest to state the confusion yet existing on the nature and identification of mammalian *Anaplasma*-like bodies and the classification of Carpano[5] should here be recorded :—

1st group.—Karyolytic masses caused by nuclear delysis due to the introduction of chemical anæmia producting substances or to toxins of microbes or metazoa—*Pseudoanaplasma*.

2nd group.—Stages on the evolution cycle of some *Piroplasma* (*Nuttalia*, *Theileria*, *Gonderia*, etc.)—*Anaplasmoids*.

3rd group.—Microparasites constituting transitional forms between anaplasms and piroplasms and showing in experimental inoculations rare piroplasmoid forms—*Par-anaplasma* (sp. *Anaplasma centrale*).

4th group —Microparasites which may be transmitted in a pure stage-*Anaplasma* (sp *A marginale*)

In 1924, Franchini[6] described in the blood of a bird some interesting bodies, which may give rise to some confusion with the parasites we are describing In fresh blood they appeared as " de petits corps qui avaient plutôt l'aspect de vacuoles " In stained smears " les parasites les plus jeunes ont l'aspect d'une petite tâche colorée faiblement en bleu, ensuite cette tâche augmente de volume, se disposant en forme de virgule, mais plus souvent en forme de demicercle ou de cercle complet Les parasites sont parfois isolés, mais plus fréquemment réunis à plusieurs dans le même globule rouge et à ce stade le protoplasme est uniforme A un stade plus avancé, les corps en question augmentent de volume, ils prennent une forme ovalaire ou plus souvent arrondie en forme de bague Leur protoplasme est plus foncé et il n'est pas rare de voir à son intérieur un noyau compact ou composé de grains de chromatine Le contour du parasite est très apparent, il devient épais et chez le parasite adulte son épassieur augmente encore On pourrait croire qu'il s'agit de formes enkystées Le noyau du parasite est toujours unique, il n'y a pas de nucléole et jamais nous n'avons pu voir des formes de multiplication Le protoplasme ne contient pas de pigment Il ne s'agit ni d'un Piroplasme ni d'un Anaplasme Il ressemble à certains hèmatozoaires décrits antérieuremens par Balfour "

Yes, such bodies were first described by Balfour[7] and his Plate VI is extremely clear They were believed by Balfour to constitute the *after phase* stage of fowl spirochætosis This hypothesis is again referred to in the Fourth Report[8] In 1929, Curasson and Andrjesky,[9] through some inoculation experiments, definitely state that the " Balfour Bodies " do not belong to the cycle of Spirochætes and Brumpt, discussing this paper, says " Au cours d'une mission récente en Égypte j'ai eu l'occasion de discuter la nature des corps de Balfour avec le professeur M Carpano . Cet Auteur a démontré la nature parasitaire de ces corps en les inoculant à des animaux sensibles, il à donné à ces corps qu'il considère comme des piroplasmidés le nom d'*Aegyptianella pullorum* . . Les très interessants germes découverts par Balfour qui au début de ses recherches, les considérait comme voisins des representants de la famille des Piroplasmidés, doivent d'après Carpano et moi être classés dans cette famille, mon opinion est que ces êtres présentent surtout des affinités avec des parasites du genre *Ansplasma* "

These "after phase bodies", whose nature and structure is very different from that of the parasite which constitutes the object of this paper, have also been found in fowls by Bouet (1909) in French Soudan, by Dschounkowsky and Luhs in Transcaucasia, by Yowet (1910) in Cape Town, Donatien and Lestoquard (1930) in Alger and by Yakimoff in Caucasia They are now classified as ***Aegyptianella pullorum*** Carpano (1929) (syn ***Aegyptianella granulosa*** Brumpt)

* * *

A parasite entirely similar to ours has been described by Cerruti[10] The coloured plate which illustrates his paper does entirely agree with our figures excepting his pyriform, cucumber-like organism depicted in Fig 4 His description is also very suggestive in fresh blood "i corpuscoli si presentavano all interno dell 'emazie come picoli corpi rotondi molto refringenti la luce, quasi immobili o dotati di movimenti di vibrazione piuttosto vivaci e di lenti movimenti di traslazione, per cui potevano spostarsi lentamente nell' interno della emazia" Stained by May-Grunwald-Giemsa "i granuli si coloravano in azurro scuro piu o meno carico, tendente al bleu, la loro colorazione non era sempre uniforma, in fatti accanto ai elementi colorati intensamente, ve ne erano altri che assumavano molto debolmenti la sostanza colorante Generalmente i granuli in questione si presentavano sotto forma rotonda, simili a cocchi (tipo anaplasma) ma analogamente aquelli de *Testudo græca* prendevano talvolta una forma ovale o nettamente bacillare (tipo *Bartonella Grahamella*), qualcuno assumeva la forma incurvata o reniforme od a rachetta Nei preparati allestiti specialmente dalla milza, erano evidenti forme molto piu grandi, rottondeggianti o costituite da un anello periferico debilmente colorato in azzuro, limitante un vacuolo incolore e colorato molto debilmente Internamente i corpuscoli apparivano ben limitati nel protoplasma della emazie, talvotta invece detto protoplasma formeva intorno ad esse un alone vero e proprio"

Excepting for the *Bartonella* and racket-like forms every line of the description of Cerruti could be applied to our parasite

Cerruti has classified this parasite in the genus *Grahamella* and named the sp *G. Thalassachelys*

The genus *Grahamella* was created by Brumpt in 1911[11] for the bacillary basophil parasites included in red cells of moles and first seen by Graham Smith[12] in 1905 "Leur aspect est bacilliforme . Certains éléments sont sphériques ou ovoides et mésurent un diamètre moyen d'un tiers de micron". Such bodies were also described and figured by Balfour[13] in two excellent micro-photographs where the red cells are seen filled up with rods and very minute rods, an aspect familiar to every one having come across with *Grahamella* In the Fourth Report, Balfour figures the appearance of these bodies stained by Romanowsky (his Plate VII, Fig 5) and if he is somewhat reticent about their nature, he agrees definitively with the opinion of Brumpt in 1911 [14] Brumpt continues "Ces corpuscules se colorent parfois d'une façon homogène intense par le Giemsa, le plus souvent ils ont leurs extrémités fortement colorées et le milieu est clair, c'est ce que l'on voit surtout dans les formes que je considère comme étant en voie de division (his Text-Figs I, E G H)

Important to note is the process of division "une forme longue s'étrangle vers le milieu qui devient clair, tandis que les pôles se colorent intensement par suite de la condensation du protoplasma, l'étranglement s'accentue, la section s'effectue, il en resulte deux éléments arrondis ou ovalaires fort colorés que s'allongent et se reproduisent de nouveau Dans certains cas la division est inégale et constitute un bourgeonnement "

Brumpt defines the genus in the following way " Parasites arrondis ou bacilliformes, vivant dans les hématies des vertébrés, se reproduisant par division transversale et par bourgeonnement Sp typ *Grahamella talpæ*

The word *arrondis* does not apply certainly to such a large form as ours, but to the minute granules which fill the red blood-corpuscles of some mammals and giving a look to the illustrations inserted in page 1057 of Wenyon's *Protozoology*, we are doubtful whether the large anaplasmoid bodies of his Figs 1, 2, 13 and 31 will belong to the same type as the *Grahamella* of the other figures

After this long discussion and a good personal knowledge of *Grahamella* such as they are found in the blood of some mammals, we come to the conclusion that our parasite and that of Cerruti cannot be included in the genus *Grahamella*

We cannot identify our parasite to the genus *Pirrhæmocyton* (Chatton and Blanc, 1914), because whatever be the validity of the genus, the presence of the parasite in the red cell was associated with the appearance of a globular albuminous body in another part of the cell

The genus *Cingula* (Awerinzew, 1914), on whose parasitic nature Wenyon has expressed his doubts, has some resemblance with our parasite But this so-called parasite occurs as a small granule surrounded by a clear area and later on a vacuole appears, converting it into a ring on one side of which a nucleus could be seen Division into two is then said to take place Johnston described in 1917 similar bodies, in two snakes from West

Africa (*Echis carinatus* and *Causus rhombeatus*) under two types one staining in homogeneous blue colour after Giemsa or Leishmann, while the other was granular and stained red [15] As the bodies we are describing resemble very much those found by Johnston, we will quote his own words "a small, spherical, hyaline, body, appearing in the red cells, taking a clear pale blue with Giemsa's or Leishmann's stain and occasionally showing a more darkly staining spherical centre Associated with this is usually another body of similar shape but often somewhat smaller—both bodies vary considerably in size—finely granular in appearance, taking a dull red stain"

In the parasite of Johnston it seems that the affected erythrocyte "as a rule stains somewhat poorly, it may contain vacuoles, one or more The nucleus is often smaller and more rounded than that of a normal cell, it may be apparently degenerating, staining poorly and showing vacuolation or it may even be absent"

The author is very reticent about the nature of these bodies whether they are parasites "though it may be considered probable They may perhaps be a new species or perhaps some stage in the development of a parasite already described, such as a hemogregarina"

Carini in 1930[16] described in the *Leptodactylus pentadactylus* from São Paulo, Brazil, some bodies which are very similar to our and Cerruti's parasite "àl'examen direct petites vacuoles qui, étant plus refringentes et incolores, se détachent dans le protoplasme de l'hématie. se colorent en bleu par le Giemsa, parfois il n'y a qu'un petit anneau périphérique qui se colore en limitant une vaucole, mais dans les préparations mieux réussies on voit un granule plus intensément coloré"

After vital staining "les corpuscles se colorent en quelques minutes et apparaissent avec une grande nettete dans les globules presque incolores Généralement ronds ou ovalaires, leurs dimensions sont variables, les plus petits sont de la grosseur d'un coccus tandis que les plus gros ont un diamètre de 1–2 microns Dans les plus gros, on distingue une partie colorée en rose qui contient un granule bleu foncé autour des corpuscules on voit parfois dans le protoplasma de l'hématie une zone circulaire plus pâle Les hématies parasitées ne sont pas altérées

Carini finds that they have affinities with *Anaplasma*, *Aegyptianella*, *Grahamella*, *Bartonella*, *Eperythrozoon*, but cannot be included in any of these genera and proposes to this parasite the name *Bertarellia leptodactyli*

Brumpt and Lavier have described under the name *Pirrhæmocyton* a parasite of *Lacerta viridis* which seems to us very similar to ours

The authors give firstly a short description of *P tarentolæ* apud Chatton and Blanc (*a*) young spheric elements, 1–4 micr , clear amæboid outline, possessing in their interior one or many chromophyl masses "Celles-ci affectent des formes très variées ; elles sont soit entières, soit bi, tri, quadrilobées, ou bien ces lobes sont séparés, formant autant de masses distinctes de tailles diverses" In some of these parasites it may be seen that "même lorsqu'ils ne sont pas au contact du noyau de l'hématie, leur masse chromatique se trouve unie à ce dernier par un tractus filiforme très colorable qui se termine soit en pointe, soit plus souvent par une capitation très nette", (*b*) spheric masses, 3,5 micr , without surrounding cytoplasmic area, "leur chromatine est divisée en fins granules, rangés à la péripherie, sauf un corpuscule qui reste central" Important to note, as we have said above, is that in all parasitised erythrocytes there is "une inclusion globoide, mesurant 1-8 micr , independente d'ailleurs structuralement du parasite, mais liée à sa présence, refringente à frais, homogène et cyanophile et représentant une reaction de l'erythrocyte parasité"

Brumpt and Lavier do not find this body in the red cells of *L viridis* and nonobstant they classify their parasite as *P lacertæ* whose following stages are described by the authors (*a*) anaplasmoid, homogeneous body, often surrounded by a light cytoplasmic halo, which sometimes at the contact with the cell proptoplasm takes a bluish stain Forms where the cytoplasm has the appearance of fine lilac granulations around a central chromatic dot are not rare Diamètre up to 4 micr , (*b*) spheroidal masses 2, 4, 5 micr , outline rather irregular, showing amæboid movements, chromatic mass single, often multilobated, or composed of 2, 3, 4 independent dots Sometimes a chromatic filament seems to start from the nuclear mass and project to the periphery, constituting in small forms the leishmanoid aspect already recorded by Chatton and Blanc , spherical masses of 5 or more micr "avec plusieurs petits grains chromatiques massés dans un seul hémisphère . nous n'avons jamais observé de granule occupant le centre et il nous semble avoir eu affaire seulement à un nombre restreint (6 en général) de granulations chromatiques, non sphériques mais légèrement allongées, de tailles souvent inégales, et présentant une disposition assez regulière"

The parasite was successfully inoculated to other lizards of the same species. The authors say "fait important, si Chatton et Blanc ont signalé, comme nous l'avons dit, la présence constante d'une inclusion globoide dans chaque globule parasité, chez notre lézard, les erythrocytes ne montraient pas la moindre réaction ni de ce genre, ni d'aucun autre Néanmoins notre parasité sans être identique à celui de la tarente, est certainement extrêmement voisin, aussi proposons nous de le nommer ***Pirrhæmocyton tarentolæ*** n sp

We don't agree with Brumpt and Lavier in this identification Their parasite is not a *Pirrhæmocyton* and seems of the same nature as the parasite we are describing in this paper, for which we maintain the genus *Bertarellia* Carini, (1930), classifying it as a sp n which we will name *Bertarellia calotis*

N B—Prof Carini in a private letter, emphasizing that the genus *Bertarellia* belongs to the ill-defined group of *Bartonella*, *Pirrhæmocyton*, *Grahamella*, *Aegyptianella*, *Tunetella* etc , and pointing out that the parasitic nature of *Bertarellia* is probable, but not demonstrated, has promised to send us slides of Brazilian tortoise blood containing bodies similar to those described by Cerruti [10] As we have also found *Bertarellia* in the blood of the Indian tortoise *Emyda granosa*, the definite characteristics of all these genera, together with the description of the tortoise *Bertarellia*, will be the subject of a further paper

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Froilano de Mello &
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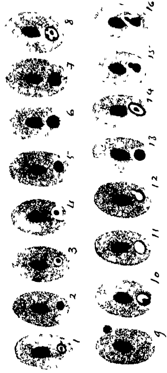

STUDIES IN SOIL BACTERIA OF THE SUBTROPICAL REGION—PUNJAB, NORTH INDIA.

By Jagjiwan Singh, M.Sc. (Punjab), Ph.D. (London),
Lecturer in Botany, Government College, Lahore.

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1. *Introduction.*

A good deal of quantitative work has been done in other countries as regards the seasonal or daily variations in bacterial numbers in order to correlate such variations with soil fertility and physical factors such as temperature, moisture and rainfall, etc. In India, however, as far as it could be traced, no such work has so far been carried out and it appeared highly desirable to investigate the type of fluctuations occurring in our field soils during different seasons of the year—seasons which are so particularly marked in the Punjab. In the Punjab, seasons of the year can be divided into four distinct types. (1) Hot summer from middle of May to middle of September. The temperature during this period goes sometimes as high as 120° F. (2) Autumn months from middle of September to middle of November. (3) Cold winter extends from middle of November up till the middle of March. The temperature during the cold months goes as low as 32° F. or less. (4) From the middle of March to the middle of May is the spring weather. Keeping in view the marked changes in seasons in the Punjab, the present work was undertaken to investigate the following points: (*a*) What is the state of the bacterial population in the Punjab soils with particular reference to its quantitative aspect? (*b*) What are the changes that are taking place in the bacterial population in our field soils during the different seasons of the year?

2. *Previous Work.*

Hiltner and Störmer (1903) found little differences between bacterial numbers in summer and winter. Remy (1902) and Wojtkiewicz (1914) have reported highest numbers of bacteria in spring. Given and Willis (1912), on the other hand, found highest numbers in September. Brown and Halverson (1919) found two maxima in February and in June. Wilson (1930) working on variations in *Rhizobium* sp., found a drop as winter advanced. In spring the numbers increased till June. He found two maxima in October and June and one minimum in January. Snow (1926–35) found while studying the micro-organisms of wind-blown soils, two maxima in January and July and one minimum in February Cutler, Crump and Sandon (1922) have reported one maximum in November, a minimum in February and a second maximum at the end of June Their curves did not correlate with seasonal changes in soil temperature and moisture. Löhnis and Sabaschnikoff (1912), Müntz and Gaudechon (1912), Wojtkiewicz (1914), Russell and Appleyard (1917), Lemmermann and Wickers (1920) have all reported greater stimulation of chemical processes in the soil either in spring or autumn or both

As regards the relation of bacterial numbers with physical factors Waksmann (1916 & 1932), Dixon (1928), Thornton and Gray (1930), Newton (1930) found no correlations with either the soil moisture or temperature Conn (1910), Russell (1913), Harder (1916), Lockhead (1923), Mary-Jo-Cobb (1932) have, however, pointed out that bacterial numbers and soil moisture are closely related to each other

3 *Experimental Work and Technique*

Two plots were selected in the Government College Botanical Gardens for experimental work One of these plots was manured with farmyard manure for a number of years and was thus named as manured plot In the other plot no manure was put and was called as an unmanured plot This prepared us to see seasonal changes in both the kinds of soils The methods used for sampling, suspension, disintegration, dilution, plating, incubation and enumeration, etc, are those suggested in appendix, Russell (1932)

4 *Results*

Date	Plot	Moisture %	Average Colony count of five plates	Standard error
14th December 1935	Manured	17·88	85 8	± 2·9
	Unmanured	15·00	51·0	± 1·58
25th December 1935	Manured	20 48	54 8	± 2·80
	Unmanured	18·00	29·6	± 2·37
11th January 1936	Manured	18·56	87·2	± 4 15
	Unmanured	16·38	74 0	± 3·60
25th January 1936	Manured	18·10	51·6	± 2·65
	Unmanured	15 66	29·2	± 2·00

Results—(Contd)

Date	Plot	Moisture %	Average Colony count of five plates	Standard error
8th February 1936	Manured	21·96	82·4	± 2·84
	Unmanured	21·548	60·6	± 2·46
23rd February 1936	Manured	19·46	64·2	± 5·00
	Unmanured	18·12	64·4	± 4·30
7th March 1936	Manured	16·68	58·2	± 2·00
	Unmanured	15·80	44·2	± 3·30
21st March 1936	Manured	21·28	85·4	± 4·00
	Unmanured	20·50	95·2	± 5·70
6th April 1936	Manured	23·04	127·0	± 8·00
	Unmanured	21·14	111·6	± 7·01
18th April 1936	Manured	15·80	126·8	± 5·10
	Unmanured	15·38	94·75	± 3·80
4th May 1936	Manured	18·92	222·20	±12·70
	Unmanured	16·04	199·40	± 5·00
5th May 1936	Manured	13·84	198·20	± 7·00
	Unmanured	12·64	159·00	± 4·10
30th May 1936	Manured	8·20	151·40	± 4·90
	Unmanured	5·00	117·00	± 5·60
15th June 1936	Manured	16·52	133·80	± 2·40
	Unmanured	15·06	128·00	± 3·50
27th June 1936	Manured	17·40	153·80	± 4·50
	Unmanured	14·16	134·60	± 7·00
11th July 1936	Manured	19·52	119·20	± 6·9
	Unmanured	17·12	102·00	± 6·3
26th July 1936	Manured	13·24	104·20	± 6·3
	Unmanured	11·16	96·20	± 8·2
8th August 1936	Manured	10·32	69·40	± 2·7
	Unmanured	8·40	58·00	± 4·1
26th August 1936	Manured	22·00	93·60	± 2·5
	Unmanured	17·76	71·80	± 4·2

Results—(Contd.)

Date	Plot	Moisture %	Average Colony count of five plates	Standard error
5th September 1936	Manured	15·50	81·20	± 3·2
	Unmanured	14·60	72·60	± 2·9
19th September 1936	Manured	17·64	105·80	± 5·4
	Unmanured	16·62	82·50	± 3·0
3rd October 1936	Manured	18·80	115·00	± 7·3
	Unmanured	17·54	150·06	± 4·1
17th October 1936	Manured	17·36	216·00	±11·1
	Unmanured	16·92	166·30	± 4·3
1st November 1936	Manured	22·21	87·60	± 4·36
	Unmanured	20·20	97·00	± 6·50
14th November 1936	Manured	22·72	79·80	± 2·70
	Unmanured	19·04	83·30	± 2·10
28th November 1936	Manured	16·20	115·00	± 2·17
	Unmanured	15·80	102·30	± 4·60

5 *Discussion*

It has been pointed out that the main object of this work was to see the effect of various seasons and other physical factors upon the bacterial numbers in our field soils. It is desirable that they should be discussed separately since these factors play such an important part and their intensities are so very well marked.

Seasonal effect.—The graph, Fig. 1, of the bacterial numbers of the manured and unmanured soils, show that there are two maxima, one sometimes in October and the other towards the end of April or beginning of May, and there are two minima in the end of January and in the first week of August. Our results have hence shown that there is a marked periodicity of the bacterial population in the soil—a rise of numbers in spring and autumn, and a distinct fall in summer and winter. These results are in general concordance with those of Russell and Appleyard (1917), Brown and Halverson (1919), Cutler and his associates (1922), Wilson (1930) and others, while on the other hand, Hiltner and Störmer (1903) found little differences between bacterial numbers in summer and winter. It may

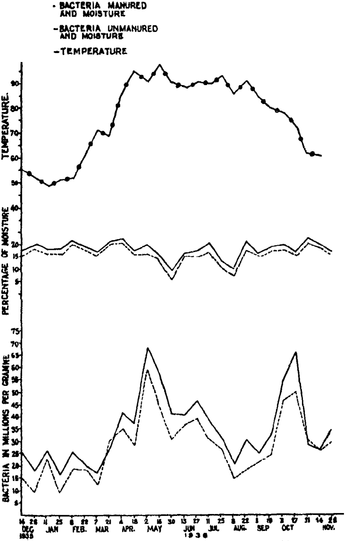

Fig. 1. Fortnightly Averages of Bacteria, Moisture and Temperature Manured and Unmanured Plots

further be pointed out that our maxima and minima occur at different times of the year and this one might have been expected since our conditions are different from those of all the other workers

Influence of soil moisture —When curves, Fig 1, for average moisture contents and average numbers are compared in greater detail, it becomes impossible to draw any generalization Thus in winter the numbers have been low but the moisture contents were fairly high, while in summer the moisture had naturally decreased and there was as well a decrease in numbers, but there does not seem to be an apparent correlation since the two decreases are not simultaneous or nearly so In the beginning of June, for example, the moisture contents are at its minimum but the numbers are fairly high and the reverse is the case towards the middle of August—numbers very low but moisture contents fairly high In general it can be stated that there is no definite relation of the bacterial numbers with the moisture present in the soil Our results hence accord with the results of Remy (1902) and Wojtkiewicz (1914), Given and Willis (1911-12), Waksmann (1916), Brown and Halverson (1919), Cutler, Crump and Sandon (1922), Thornton and Gray (1930), Newton (1930)

Hiltner and Stormer (1903), Conn (1910), Russell (1913), Harder (1916), Lockhead (1924), have found a correlation of the numbers with the moisture contents

Influence of rainfall —It has been suggested by Russell and some other workers, that a heavy shower of rain by increasing the aeration of the soil population may have beneficial effects upon the micro-organisms In our case, however, rainfall cannot be said to have marked effect, on the changes in numbers since they occurred even when there was no rainfall Thus the greater part of autumn and spring rise in numbers occurred when no rain fell for a considerable time preceding these months

Influence of temperature —That the temperature has effect on the bacterial numbers is apparent from the graph, Fig 1 With the rise of temperature from winter months the bacterial numbers also show a corresponding rise which seem to continue with certain optimum temperature limits Then with persistent high temperature the numbers show a decrease Again with the lowering of the temperature and probably with the partial removal of the bad effects of high temperature to the bacterial numbers, there is a tendency of recovery It may be stated, however, that the effect of temperature on the bacterial population is accumulative in nature A persistent low temperature decreases the numbers as in winter, then a rise in temperature has a wholesome effect as in spring A continuous high temperature has a tendency of keeping the numbers down as in summer, and lastly the numbers again rise up with slight lowering of the temperature as in autumn.

Hiltner and Stormer (1903), Cutler, Crump and Sandon (1922), Dixon (1928) did not find any correlation between the bacterial numbers and the temperature, but the finding of Given and Willis (1911-12), Brown and Halverson (1919) definitely support this

Influence of chemical changes in the soil —No special chemicals were tried but from the two kinds of plots it is definite that one which contained more organic matter has more organisms both in numbers and types

In the end it may be pointed out that the maximum bacterial activity in our parts is manifested from the middle of April to the middle of May in spring, and from the middle of September to the middle of October in autumn One may as well reasonably assume that the availability of other plant nutrients such as nitrates, ammonium-salts, potassium, phosphates, etc , may also be at their maximum somewhere in the months noted above On reviewing the crop sowing operations in the Punjab, it is noted that wheat is grown sometimes in October and is harvested in April or May Sowing of cotton is done in May or so along with some other leguminous crops, and harvesting is effected in September or October These are the two most important crops in the Punjab, of course, so many other types of crops are grown as well—sugarcane, vegetables, etc From the above farm operations it is quite apparent that the months of maximum activity—April-May and September-October—are not utilised as they should be, in the process of the growth of crops During the above-noted months of great biological activity, the fields are almost without any crops, and it may be suggested that farm operations may be regulated in such a way that the high available plant food materials in spring and autumn in the above-noted months should be utilised by the growing crops in some form or another.

Qualitative —A few words may be said about the floristic characteristics with regard to the soil bacteria No attempt was made to make a detailed study of the different types of bacteria occurring in our soils But during the course of the work attention was kept on a spreading type of a ***Bacterium***, since this form very easily overran some of the plates It was noticed that this form was hardly visible on the plates in winter months but with the rise in temperature in March and April it could very easily be seen. Again in very hot summer months no trace of the type could be found and it again became apparent in the beginning of autumn months.

It is quite probable that this spreading type may have some relation with temperature or with some other external factors, and it is not unlikely that some other less conspicuous forms in the soil may be appearing and disappearing with different seasons of the year

6 *Summary and Conclusions*

I. In this paper the seasonal variations for bacterial numbers have been described in manured and unmanured field soils in the Punjab

II Two maxima in the middle of October and beginning of May, and two minima in the end of January and in the first week of August were obtained

III The variations of bacterial numbers in the soil cannot be explained as entirely to be due to any of the physical factors individually, but may be the result of the accumulative effect of all the factors of which the temperature seems to be the most important

IV It may be stated that in our soils the number of bacteria as occurring on the plate method is higher than those reported by the European and American workers

V Different types of bacteria seem to be appearing and disappearing at different seasons of the year as indicated by a spreading type of *Bacterium*, but an exclusive study of this problem is desired before any definite statement could be made

The author wishes to express his thanks to Mr H Chand who helped during the course of the work in doing plating sometimes

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SOME STUDIES ON TEMPERATURE OF THE COTTON PLANT IN THE PUNJAB.

By Jai Chand Luthra, M.Sc , D I C , I A S , R S
AND
Indar Singh Chima, M Sc (Ag)
(From the Punjab Agricultural College and Research Institute, Lyallpur)

Received June 10, 1937
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I *Introduction*

It is well known that temperature as an environmental factor has a marked influence on the various life processes of a plant, *i e*, respiration, transpiration, root absorption, etc According to Vant Hoff's rule (*1896*) " The rate of chemical reaction doubles for a rise in temperature of 10° C " Its effect on economic crops is particularly a matter for instructive and useful study in the Punjab, where the air temperature rises sometimes to 118° F. in summer and falls below zero in winter American cotton, to which the investigation reported in the paper relates, is cultivated almost exclusively in the canal colonies, where the plant has to adapt itself to extremes as well as to fluctuations of temperature and humidity during its growing period, which extends from April to December The measurement of temperature of the cotton plant was undertaken to ascertain the extent to which the plant adjusts itself to atmospheric heat under such trying circumstances There have been successes and failures of American cottons in this Province and it seems likely that unfavourable years were chiefly the results of adverse climate conditions and some soil factors particularly moisture contents

References to earlier work on plant temperatures as far as the writers have been able to obtain are the following —

Clum (1926) while taking the temperature of leaves of *Fuchsia speciosa, Phaseolus vulgaris, Brassica oleracea* and *Syringa vulgaris* observed that, in gneral, plants in dry soil, and vaselined leaves were 2° to 4° C warmer than the controls Balls (1912) working on cotton leaves in Egypt reports that the temperature of old leaves rarely fell below air temperature, but frequently rose above the air temperature by 3° C to 10° C Eaton and Belden (1929) in U S A report that the leaf temperature of cotton plants are correlated with transpiration, varietal differences and yields The yields of the upland varieties were distinctly higher in 1923 than in the hotter vears 1922 and 1924 • Miller and Saunders (1923) while studying the temperature-transpiration relation of the leaves of corn, sorghum, cowpeas, soybeans and watermelons growing under field conditions, found that the temperature of leaves never remained constant They also found that the temperature of the wilted leaves of corn, sorghum, etc , remained 1·85°, 1·55°, 2·8° and 4·65° C higher than the temperature of turgid leaves Ezekiel and Taubenhaus (1932) found that the leaves of cotton plants, wilted from *Phymatotrichum* root-rot were as much as 6·5° F warmer than the air Seeley (1917) in Michigan found the temperature of strawberry leaves on clear days to be 8 4° C above air temperature Trought (1931) states " The temperature of the leaves follows closely the temperature of the surrounding air For cotton, unpublished figures obtained by R S Jai Chand Luthra confirm this fact "

II *Method of work and apparatus employed*

Determinations of temperature have been made on 4F cotton plant—a Punjab acclimatised upland American cotton (*G hirsutum*) The work was started in 1928 and has been in progress since then For this purpose, leaves of the same size, and of comparable age 30–35 days old and those hanging at right angles to sun on the secondary branches and at the height of about 2 feet were always selected on a single plant Temperatures of the upper and lower surfaces of the leaf and the internal tissue of the midrib and the petiole were measured. As the temperature of the leaf was found to fluctuate rapidly, six determinations were taken each on a different leaf and the average value was recorded. The standard error for these sets of six figures ranged from ·1 to ·6 and is statistically sound.

Variations of temperature are associated with a number of factors The following are some of the factors studied —

(A) The surrounding air
(B) Soil moisture
(C) Moisture content of leaves
(D) Age of leaves
(E) Wilting of leaves

Apparatus —The apparatus (Fig 0) used for the determination of temperature was devised on the principle of thermo electricity by modification of the one used by some American workers It consists of two thermo-junctions, a galvanometer and a spring key The thermo-junctions were constructed by soldering the ends of a constantan wire No 32 to one end of each of two copper wires No 36. The absorption coefficient of the wires was nil The free end of one copper wire was connected with a key and that of the other to a galvanometer, thus forming a complete circuit The wires were insulated One of the thermo-junctions was inserted into the neck of a stoppered Dewar's flask along with a thermometer Hot water was put into the flask in winter and cold water in summer The bulb of the

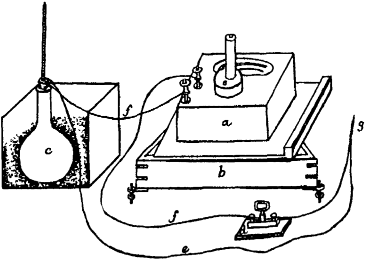

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FIG 0. *a* Galvanometer, *b* Levelling Tripod stand, *c* Thermos flask, *d* Key, *e* Constantan wire, *f* Copper wire, *g* Free junction thermometer was dipped into the water The Dewar's flask was placed in a box filled with sawdust The temperature of the water in the Dewar's flask was constant The second thermo-junction was held in a clamp in such a way that it would be conveniently placed upon the leaf surface. The clamp consisted of a pair of brass tongs to the ends of which pieces of cork were glued For determining the temperature of the inner tissue the free thermo-junction was inserted into the petiole or midrib The temperature of the atmosphere was taken by holding the free junction in the air and placing it in a position where air played freely on it at a height of 2 feet from ground level Necessary precautions were taken to screen the thermo-junctions from direct sun rays A pivot galvanometer No L 27156 manufactured by the Cambridge Instrument Company, Ltd , England, sensitive enough to indicate at least 0 0025 micro-amperes was placed in a circuit along with a spring key Since the temperature of the thermo-junction in Dewar's flask was known and constant, the difference in temperatures between the two junctions could be shown by a swing of the indicator of the galvanometer. The galvanometer was placed on a levelling tripod, which could be adjusted to get a level surface for the galvanometer The whole apparatus was kept in a cabinet to protect it from the sun (Plate XIII)

III (A) Relationship between the leaf temperature and the surrounding air

Work was started in 1928 and has been continued upto 1934 The data of 1931 are reported herein The work was repeated during the years 1932, 1933 and 1934, and the results obtained when compared with the data of 1931 showed minor differences, which are accounted for by differences in relative humidity, soil moisture and variation in leaf moisture content resulting from different amounts of rain received during the growth period of the plant However, the general trend of results is the same and there is a corroboration of the results of 1931 Seed of a pure strain of 4F cotton was sown in May each year in a typical field of the botanical area at Lyallpur Representative plants of the crop were marked for temperature determinations For the first three years and for June and July of 1931 leaf temperatures were taken thrice daily at 7 A M , 1 P M and 7 P M respectively. The data collected during three years' work was studied and it was considered that three observations during the day at an interval of six hours did not furnish sufficient data to study fully the range of variability of leaf temperatures from that of the air. Consequently from August 1931 onwards the work was extended and determinations were made every two hours throughout day and night during August and September and for the-day only during October and November The results obtained during different months are as follows —

June and July 1931 —Leaf temperatures were taken thrice daily and the results obtained are given in Table I In the morning and evening plants show air temperature During the middle of the day the temperature of the plant is lower by about two degrees and the variability is found to be greater than at the other hours

TABLE I

Monthly mean departures of leaf temperatures (columns 4 6) from air temperatures (column 3) during June and July 1931

"Irrigated crop"

Month	Time	Air temperature in degrees C	Upper surface	Lower surface	Inner tissue	
					Petiole	Midrib
1	2	3	4	5	6	
June	7 A M	28 7	— 2	— 5	— 1	— 2
	1 P M	37 5	-2 0	—3 0	—2 3	—3 1
	7 P M	32 0	+0 2	+0 2	+0 0	— ·1
July	7 A M	28 4	+0 5	+0 4	+0 4	—0 3
	1 P M	40 0	—1 8	—2 8	—1 7	—2 9
	7 P M	34 6	+0 3	— 1	— ·4	— ·2

Note —It is realized that full information can only be got from daily variations, but as it is not feasible to record such cumbersome data, monthly means are given To supplement this information, data of highest and lowest departure are also noted in the remarks column where necessary

July 1932 —In July 1932 readings were taken every three hours during the day, and the data are given in Table II, Fig 1 It will be seen that leaves have almost the same temperature as the air at 6 A M, but then they gradually begin to be warmer and at 9 A M there is a rise of about 1° to 2·5° C above the air temperature Afterwards there is a slow fall and the leaves remain cooler than the air by about 3° to 4° C till evening, when they again acquire the temperature of the air

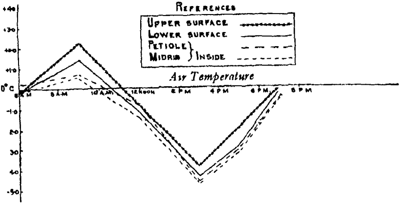

FIG 1 Monthly mean departures of leaf temperatures of irrigated 4F Cotton Plants from air during July at different periods of the day.

TABLE II

Monthly mean departures of leaf temperatures (columns 3–5) from air (column 2) during July 1932 (Irrigated crop)

"Bud formation" Stage

Time	Air temperature in degrees C	Upper surface	Lower surface	Inner tissue	
				Petiole	Midrib
1	2	3	4	5	
6 A M	29·1	− ·2	− ·1	+ ·1	− ·2
9 A M	33·8	+2·2	+1·3	+ ·5	+ ·4
12 Noon	38·6	− ·9	−1·2	− ·9	−1·3
3 P M	40·5	−3·9	−4·3	−4·6	−4·8
5 P M	38·2	−1·9	−2·9	−3·0	−3·1
7 P M	33·7	− ·1	− ·2	− ·5	− ·5

II

Comparison of mean departures of leaf temperatures from air on July 15th, 1932

" Irrigated crop "

Hours of observations	Mean Temperature of air in °C	Mean Temperature of Upper Surface in °C	Mean Temperature of Lower Surface in °C	Inner tissue		Remarks
				Mean Temperature of Petiole in °C	Mean Temperature of Midrib in °C	
6 A M	30 0 ± 20 Difference from air temperature	29 0 ± 15 – 4 ± 25 Insignificant	29 7 ± 11 - 3 ± 22 Insignificant	29 8 ± 10 – 2 + 22 Insignificant	29 7 ± 10 3 ± 22 Insignificant	
9 A M	34 4 ± 20 Difference from air temperature	37 0 ± 30 +2 6 ± 35 Significant	36 1 ± 40 +1 7 ± 35 Significant	35 2 ± 10 + 8 ± 20 Significant	35 3 ± 10 + 7 + 20 Just significant	In the morning and evening leaves show air temperature but they are warmer at 9 A M and significantly cooler than the air in the afternoon
12 Noon	39 0 + 20 Difference from air temperature	37 8 ± 15 –1·2 ± 25 Significant	37 5 ± 18 –1 5 + 28 Significant	37 7 ± 15 –1 3 ± 25 Significant	37 4 ± 15 –1 6 ± 25 Significant	
3 P M	41 2 ± 45 Difference from air temperature	37 0 ± 40 –4 2 ± 60 Significant	36 8 ± 30 – 4 4 ± 54 Significant	36 7 ± 40 – 4 5 ± 6 Significant	36 8 + 35 –4 4 ± 57 Significant	
5 P M	38 6 ± ·40 Difference from air temperature	36 2 ± 30 –2 4 ± 5 Significant	35 0 ± 15 –3 6 + 45 Significant	35 2 ± 40 –3 4 ± 56 Significant	35 1 ± 40 –3 5 ± 56 Significant	
7 P M	34 4 + 30 Difference from air temperature	34 0 ± 20 – 4 ± 46 Insignificant	33 9 ± 16 5 + 33 Insignificant	33 8 ± 15 – 6 ± 33 Insignificant	33 7 ± 12 – 7 ± 32 Insignificant	

August 1931 —The data obtained are summarised in Table III and graphically represented in Fig 1(*a*) For convenience and brevity, cotton temperatures represented in the tables and figures are given as departures from the air temperature which is shown as a straight line in the figures and is taken as zero It is found that the temperature of the leaves is never constant and keeps on fluctuating with that of the air In the morning at 6 A M the leaf temperature almost coincides with the air The lower surface and the inside of the midrib are, however, cooler by about

1° C Afterwards it begins to rise gradually and at 8 A M it is about 5° to 6° C above the air in the case of upper and lower surfaces and 3° to 4° C

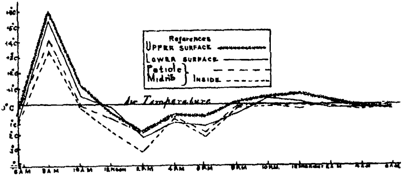

Fig. 1(a) Monthly mean departures of leaf temperatures of irrigated 4F Cotton Plants from air during August at different periods of the day

TABLE III

Monthly mean departures of leaf temperatures (columns 3-5) from air (column 2) during August 1931 (Irrigated crop)

" Bud formation—Stray flowers " Stage

Time	Air temperature in degrees C	Upper surface	Lower surface	Inner tissue		Remarks
				Petiole	Midrib	
1	2	3	4	5		6
6 A M	27 71	− 21	− 1 11	− 35	− 1 39	5th August, at 8 A M, temperature of the upper surface was + 9 0° C and at 10 A M, + 8 0° C
8 A M	28 96	+ 6 07	+ 5 37	+ 4 16	+ 3 59	
10 A M	36 56	+ 1 24	+ 50	− 13	− 20	
12 Noon	38 7	− 0	− 22	− 92	− 1 8	
2 P M	35 22	− 1 79	− 2 19	− 1 88	− 3·11	
4 P M	34 05	− 65	− 1·15	− 70	− 95	
6 P M	33 73	− ·76	− 1 47	− 1 81	− 2 07	On 13th and 14th August inner tissue showed low temperature (−2° C to −3° C) at 8 A M
8 P M	30 78	+ 10	− 06	− ·12	− 19	
10 P M	29 55	+ 40	+ 38	− 09	− ·49	
12 Mid night	29 7	+ 62	+ 0 01	− ·35	− 09	These days were cloudy,
2 A M	28 2	+ 20	− ·20	+ ·10	− 20	
4 A M	27 6	− 1	− ·24	− 20	− 40	
6 A M	27 0	− 38	− ·30	− ·08	− 05	

TABLE III

Comparison of mean departures of leaf temperatures from air on August 4, 1931

" Irrigated crop "

Hours of observation	Mean Temperature of air in ° C	Mean Temperature of Upper Surface in ° C	Mean Temperature of Lower Surface in ° C	Inner tissue		Remarks
				Mean Temperature of Petiole in ° C	Mean Temperature of Midrib in ° C	
6 A M	27 6 ± 21 Difference from air temperature	27 4 ± 31 − 2 ± 37 Insignificant	26 5 ± 302 −1 10 ± 36 Insignificant	27 4 ± 28 − 2 ± 34 Insignificant	26 9 ± 29 − 7 ± 36 Insignificant	Leaves have almost air temperature
8 A M	28 5 ± ·28 Difference from air temperature	34 7 ±1 66 +6 2 ±1 68 Significant	32 7 ±1 10 +4 2 ±1 13 Significant	32 0 ± 61 +3 5 ± 67 Significant	31 7 ± 60 +3 2 ± 66 Significant	Leaves warmer than air by about 3°C to 6°C
10 A M	35 9 ± 21 Difference from air temperature	37 0 ± 65 +1 10 ± 68 Insignificant	36 5 ± 33 + 6 ± 39 Insignificant	35 3 ± 34 − 60 ± 39 Insignificant	35 4 ± 36 − 50 ± 43 Insignificant	Leaves show air temperature
12 Noon	39 1 ± 38 Difference from air temperature	38·9 ± 37 − ·2 ± 53 Insignificant	38 6 ± ·40 − 5 ± 55 Insignificant	37 9 ± 20 −1 2 ± 42 Insignificant	36 8 ± 39 −2 3 ± 54 Significant	Do
2 P M.	35 9 ± 14 Difference from air temperature	34 2 ± ·40 −1 8 ± 40 Significant	33 4 ± ·37 −2 5 ± 39 Significant	33 3 ± 27 −2 6 ± 30 Significant	32 9 ± 44 −3 0 ± 40 Significant	In the afternoon leaves are cooler by about 1°C. to 3° C than the air
4 P M	34 2 ± 18 Difference from air temperature	33 4 ± 10 − 8 ± 2 Significant	32 6 ± 36 −1 8 ± 40 Significant	33 2 ± 13 −1 0 ± 23 Significant	32 9 ± 10 −1 3 ± 20 Significant	
6 P M	33·1 ± 10 Difference from air temperature	32 3 ± 20 − ·8 ± 22 Significant	31 2 ± 19 −1 9 ± 21 Significant	30 9 ± 21 −1·2 ± 23 Significant	30 2 ± 20 −1 9 ± 22 Significant	
8 P M	29·6 ± ·64 Difference from air temperature	[illegible] 5 ± ·7 −[illegible]1 ± ·94 Insignificant	29 6 ± 61 +0 0 ± 88 Insignificant	29 3 ± 48 − 3 ± 80 Insignificant	29 0 ± ·6 − 6 ± 87 Insignificant	In the evening the leaves acquire air temperature again

higher in the tissues of petiole and midrib From 8 A M onwards, a striking fall of temperature is observable and at 10 A M leaves acquire the air temperature except the upper surface which is a little warmer From 12 noon to 8 P M the leaves remain cooler by about 2 to 3 degrees than the air Late in the evening the temperature of leaves begins to rise and corresponds with the air temperature Throughout the night there was practically no difference between the air temperature and the temperature of the leaves At midnight a slight rise above the air temperature had occurred in the case of upper surface

September 1931 —During this month as given in Table IV and Fig 2 the leaf temperatures are more or less similar to those of August except that the maximum temperature is attained at 10 A M instead of 8 A M in August The leaves have air temperature in the morning at 6 A M There is a slow rise till 10 A M, when the leaf temperature is about 3 degrees

TABLE IV

Monthly mean departures of leaf temperatures (columns 3–5) *from air* (*column* 2) *during September* 1931 (*Irrigated crop*)

"*Maximum flowering*" *Stage*

Time	Air temperature in degrees C	Upper surface	Lower surface	Inner tissue	
				Petiole	Midrib
1	2	3	4	5	
6 A M	23 0	+ 07	+ 21	− 10	− 03
8 A M	27 59	+ 2 07	+ 1 20	+ 1 30	+ 78
10 A M	33 84	+ 3 57	+ 3 04	+ 1 90	+ 1 25
12 Noon	37 99	+ 2 37	+ 1 45	+ 1 79	+ 65
2 P M	38 66	−1 27	− 1 59	− 26	− 1 54
4 P M	37 0	− 1 33	− 1 37	− 70	− 1 27
6 P M	29 40	− 48	− 71	68	− 98
8 P M	27 7	− 22	+ 45	+ 93	+ 65
10 P M	26 78	+ 67	+ 56	+ 1 33	+ 1 51
12 Mid night	25·48	+ 04	+ 18	+ 1 00	+ 1 33
2 A M	23 84	+ 37	− 22	+ 57	+ 65
4 A M	23 98	+ 40	− 45	+ 30	+ ·49
6 A M	24·15	− ·83	− 99	+ ·28	+ ·14

TABLE IV

Comparison of mean departures of leaf temperatures from air on September 11, 1931

"Irrigated crop"

Hours of observation	Mean Temperature of air in °C	Mean Temperature of Upper Surface in °C.	Mean Temperature of Lower Surface in °C	Inner tissue		Remarks
				Mean Temperature of Petiole in °C	Mean Temperature of Midrib in °C	
6 A M	25 2 ± 31 Difference from air temperature	25 4 ± 25 + 2 ± 30 Insignificant	25 6 ± 37 + 4 ± 34 Insignificant	25 0 ± 29 − 2 ± 42 Insignificant	25 1 ± 31 − 1 ± 43 Insignificant	Leaves show air temperature
8 A M	29 0 ± 15 Difference from air temperature	31 8 ± 19 +2 8 ± 24 Significant	30 6 ± 14 +1 6 ± 20 Significant	30 8 ± 09 +1 8 ± 14 Significant	30 2 ± 03 +1 2 ± 15 Significant	Leaves definitely warmer than air by about 1°C to 4° C but the midrib acquires air temperature at 12 Noon
10 A M	35 1 ± 26 Difference from air temperature	39 4 ± 43 +4 3 ± 5 Significant	38 8 ± 51 +3 7 ± 57 Significant	37 9 ± 29 +2 8 ± 39 Significant	37 2 ± 20 +2 1 ± 32 Significant	
12 Noon	39 2 ± 31 Difference from air temperature	42 0 ± 46 +2 8 ± 55 Significant	40 9 ± 21 +1·7 ± 37 Significant	41 0 ± 16 +1 8 ± 34 Significant	40 1 ± 30 + 9 ± 43 Insignificant	
2 P M	40 0 ± 53 Difference from air temperature	37 1 ± 27 −2 9 ± 60 Significant	36 5 ± ·57 −3 5 ± 87 Significant	38 0 ± 19 −2 0 ± 62 Significant	37 8 ± 26 −2 2 ± 65 Significant	Leaves cooler than air in the afternoon by about 1° C to 3 C
4 P M	35 6 ± 36 Difference from air temperature	33 4 ± 16 −2 2 ± 38 Significant	33 0 ± 12 −2·6 ± 36 Significant	34 5 ± 09 −1 1 ± ·36 Significant	34 0 ± 10 −1 6 ± 30 Significant	
6 P M	31 2 ± 42 Difference from air temperature	30 4 ± 36 − 8 ± 65 Insignificant	32 2 ± 27 −1 0 ± 48 Insignificant	30 5 ± 29 − 7 ± 50 Insignificant	30 1 ± 38 −1 1 ± 57 Insignificant	Leaves show air temperature in the evening
8 P M.	28 9 ± 25 Difference from air temperature	28·0 ± 12 + 7 ± 27 Insignificant	29·4 ± 10 + 5 ± 27 Insignificant	29 5 ± 13 + 0 ± 28 Insignificant	29 3 ± 11 + 4 ± 27 Insignificant	

higher than the air temperature Afterwards there is a steady fall and the leaves are cooler than the air upto 4 P M by about 1 to 1·5 degrees It rises again and during night, the leaves remain slightly warmer than the air especially the inner tissue At dawn the temperature of the leaves begins to be equal to that of the air temperature

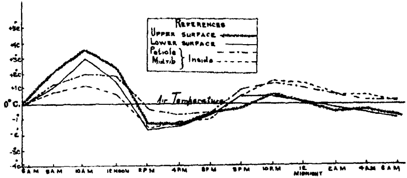

Fig. 2 Monthly mean departures of leaf temperatures of irrigated 4F Cotton Plants from air during September at different periods of the day.

October 1931 --It was observed that during the whole of October, the leaves did not behave uniformly with regard to adjustment with the air temperature Therefore the data obtained for the month is examined in two portions During the first fortnight, the variation of the leaf temperature is nearly the same as in August and September At 6 A M there is a difference of about 1° C from the air temperature (Table V and Fig 3)

TABLE V

Monthly mean departures of leaf temperatures (columns 3–5) from air (column 2) during October 1931 (1st half) (Irrigated crop) " Boll Development—Stray boll picking " Stage

Time	Air temperature in degrees C	Upper surface	Lower surface	Inner tissue	
				Petiole	Midrib
1	2	3	4	5	
6 A M	23 94	+ 81	+ 1 11	+ 96	+ 1 06
8 A M	30 20	+ 4 7	+ 4 4	+ 2 4	+ 3·0
10 A M	33 96	+ 5 25	+ 3 78	+ 2 56	+ 2 31
12 Noon	36 8	+ 3 4	+ 3 9	+ 2 65	+ 3 0
2 P M.	37 4	+ 1 2	+ 1 21	− 15	− ·09
4 P M	32 0	+ 0	− 4	− 34	− 54
6 P M	27·4	+ ·9	− ·51	− 42	+ 51
8 P M.	22 5	+ ·67	+ ·21	+ ·51	+ ·32

TABLE V

Comparison of mean departures of leaf temperatures from air on October 8, 1931

" Irrigated crop "

Hours of observation	Mean Temperature of air in °C	Mean Temperature of Upper Surface in °C	Mean Temperature of Lower Surface in °C	Inner tissue		Remarks
				Mean Temperature of Petiole in °C	Mean Temperature of Midrib in °C	
6 A M	25 1 ± 27 Difference from air temperature	26 4 ± ·13 + 1·3 ± 29 Significant	26 2 ± 19 +1 1 ± 33 Significant	26 4 ± 17 +1·3 ± 32 Significant	26 9 ± 11 +1 8 ± 29 Significant	
8 A M	29 4 ± 43 Difference from air temperature	34 4 ± 46 + 5 0 ± 65 Significant	33 3 ± 38 +3 7 ± 59 Significant	32 6 ± 40 +3 2 ± ·59 Significant	32 8 ± 25 +3 4 ± 50 Significant	From 6 A M to 2 P M the leaves are warmer than the air and differences are statistically significant but in the evening from 4 P M to 8 P M leaves show air temperature
10 A.M.	34·5 ± 38 Difference from air temperature	40·2 ± 41 +5 7 ± ·55 Significant	39 1 ± 27 +4·6 ± 46 Significant	37 2 ± 31 +2 7 ± ·37 Significant	37 5 ± 40 +3 0 ± 55 Significant	
12 Noon	37 2 ± 40 Difference from air temperature	40·8 ± 21 +3 6 ± 45 Significant	40 2 ± 17 +3 0 ± 43 Significant	39 9 ± 12 +2 7 ± 41 Significant	40 1 ± 18 +2 9 ± 43 Significant	
2 P M	38 0 ± ·31 Difference from air temperature	39 9 ± ·18 +1 9 ± 36 Significant	39 7 ± 12 +1·7 ± 33 Significant	38 5 ± 18 + 5 ± 36 Insignificant	38 2 ± 16 + 2 ± ·34 Insignificant	
4 P M	33·5 ± ·36 Difference from air temperature	33 8 ± 24 + ·3 ± ·43 Insignificant	33·7 ± 22 + 2 ± 42 Insignificant	32 7 ± 18 - 8 ± 40 Insignificant	32 8 ± 16 — 7 ± 39 Insignificant	
6 P M	26 0 ± 28 Difference from air temperature	26 2 ± 16 + 2 ± 32 Insignificant	25 5 ± 18 — 5 ± 33 Insignificant	25 4 ± ·19 — 6 ± 35 Insignificant	25 7 ± 20 — 3 ± 34 Insignificant	
8 P M.	20 9 ± 25 Difference from air temperature	21 6 ± 12 + 7 ± ·27 Insignificant	21 4 ± 10 + 5 ± 27 Insignificant	21 5 ± ·13 + 6 ± 28 Insignificant	21 3 ± 11 + ·4 ± 27 Insignificant	

The temperature then rises till 8 A M or 10 A M but at a different rate From 10 A M onwards there is a fall which continues till the afternoon At 4 P.M leaves show air temperature and tend to remain so till the evening; the upper surface, however, shows slightly higher temperatures at 6 and 8 P.M In October, night readings were abandoned on account of cold.

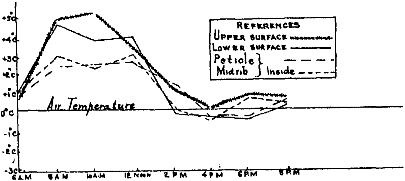

FIG. 3 Monthly mean departures of leaf temperatures of irrigated 4F Cotton Plants during October (I part) at different periods of the day

October 1931 (*2nd half*) —The most striking feature of the behaviour of leaves in this part of the month as shown in Table VI, Fig 4, is that at no time the temperature of leaves fell below the air temperature At 7 A M the upper surface and lower surface start with almost air temperature, but the temperature of petiole and midrib is higher by 1° C The departure

TABLE VI

Monthly mean departures of leaf temperatures (columns 3-5) from air (column 2) during October 1931 (*2nd half*) (*Irrigated crop*)

" *Stray boll picking* " *Stage*

Time	Air temperature in degrees C	Upper surface	Lower surface	Inner tissue		Remarks
				Petiole	Midrib	
1	2	3	4	5		6
7 A M	13 5	+ 30	+ 51	+ 96	+ 1 2	On 15th, 22nd and 28th October at 3 P M upper and lower surfaces showed temperature +10 0° and +8 0° C respectively
9 A M	21 5	+ 4 27	+ 3 63	+ 2 7	+ 3 42	
11 A M	28 4	+ 5 93	+ 3 92	+ 2 76	+ 1 73	
1 P M	31 55	+ 6 46	+ 5·00	+ 35	+ 33	
3 P M	28·66	+ 7 39	+ 6 8	+ 1 38	+ 1·84	
5 P M	22·59	+ 2 18	+ 1 8	+ 1 0	+ ·55	
7 P M	15 81	+ 98	+ 1·02	+ ·82	+ ·97	

TABLE VI

Comparison of mean departures of leaf temperatures from air on October 23, 1931

" Irrigated crop "

Hours of observation	Mean Temperature of air in °C	Mean Temperature of Upper Surface in °C	Mean Temperature of Lower Surface in °C	Inner tissue		Remarks
				Mean Temperature of Petiole in °C	Mean Temperature of Midrib in °C	
7 A M	12 0 ± ·20 Difference from air temperature	12 6 ± 18 + 6 ± ·27 Insignificant	12 7 ± 20 + 7 ± 28 Insignificant	13 0 ± 08 +1 0 ± 21 Significant	13 5 ± 05 +1 5 ± 20 Significant	The inner tissue is warmer but the upper and lower surface show air temperature in the morning
9 A M	19·5 ± 36 Difference from air temperature	24·7 31 +5·2 ± ·47 Significant	23 4 ± 26 +3·9 ± 44 Significant	22 7 ± 18 +3 2 ± 40 Significant	23 1 ± 19 +3 6 ± 40 Significant	
11 A M	24 7 ± 25 Difference from air temperature	27 9 ± 30 +3 2 ± 39 Significant	27 8 ± 25 +3 1 ± ·35 Significant	26 4 + 20 +1 7 ± 1?	26 2 ± 20 +1 5 ± 32 Significant	
1 P M	25 9 ± 40 Difference from air temperature	31 1 ± 50 +5 2 ± 64 Significant	30 2 ± ·30 +4 3 ± 50 Significant	28 0 ± 15 +2 1 ± 42 Significant	27 9 ± ·12 +2 0 ± 41 Significant	The leaves remain warmer throughout the day up to 7 P M than the air except that of inner tissue which at 7 P M shows air temperature
3 P M	26 5 ± ·26 Difference from air temperature	29 0 ± 19 +2 5 ± 32 Significant	29 1 ± 16 +2 6 ± 30 Significant	28 7 ± 11 +2 2 ± 28 Significant	28 5 ± 14 +2 0 ± 29 Significant	
5 P M	20 1 ± 30 Difference from air temperature	22 9 ± 15 +2·8 ± ·33 Significant	22 5 ± 13 +2 4 ± 32 Significant	22·4 ± ·13 +2·3 ± 32 Significant	22 6 ± 18 +2 5 ± 35 Significant	
7 P M.	14 2 ± 40 Difference from air temperature	16 0 ± 40 +1 8 ± 57 Significant	15·9 ± 30 +1 7 ± 5 Significant	15 0 ± 15 + 8 ± 42 Insignificant	15 1 ± 12 + 9 ± 41 Insignificant	

from the air temperature in the case of upper and lower surfaces goes on increasing till 3 P M when it stands at +7 39° and +6 80° C respectively After 3 P M a fall sets in and at 7 P M the temperature approaches that of the air The temperature of petiole and midrib increased upto 9 A M and then fell to that of the air at 1 P M It rose again at 3 P M At 7 P M it was about 1° C above the air temperature.

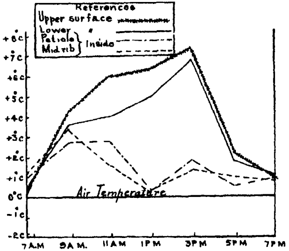

Fig 4 Monthly mean departures of leaf temperatures of irrigated 4F Cotton Plants from air during October (II part) at different periods of the day.

November 1931 —As represented in Table VII, Fig 5, the data indicate that the leaves in the morning at 7 A M have the same temperature as the

TABLE VII

Monthly mean departures of leaf temperatures (columns 3–5) from air (column 2) during November 1931 (Irrigated crop)
"Peak of boll picking" Stage

Time	Air temperature in degrees C	Upper surface	Lower surface	Inner tissue	
				Petiole	Midrib
1	2	3	4	5	
7 A M	9 0	+ 1	+ 2	+ ·0	+ ·1
9 A M	18 43	+ 4 37	+ 4 11	+ 1 39	+ 2·01
11 A M	26 94	+ 3·75	+ 3·62	+ 1·35	+ 1·15
1 P M	26 73	+ 5·22	+ 4 63	+ 1·94	+ 1·77
3 P M	26·91	+ 2 85	+ 2·58	+ 1·9	+ 1 01
5 P M	18 96	+ 3·43	+ 2·86	+ 1·98	+ 2·23
7 P.M	13 54	+ 1·70	+ 1·39	+ ·74	+ ·80

TABLE VII

Comparison of mean departures of leaf temperatures from air on November 15, 1931

"Irrigated crop"

Hours of observation	Mean Temperature of air in °C	Mean Temperature of Upper Surface in °C	Mean Temperature of Lower Surface in °C	Inner tissue		Remarks
				Mean Temperature of Petiole in °C	Mean Temperature of Midrib in °C	
7 A M	11 0 ± ·10 Difference from air temperature	11 2 ± 10 − 2 ± 18 Insignificant	11 4 ± 11 + 4 ± 19 Insignificant	11 3 ± 12 + 3 ± 2 Insignificant	11 2 ± 14 + 2 ± 21 Insignificant	Leaves show air temperature in the morning
9 A M	16 5 ± 20 Difference from air temperature	21 7 ± 25 +5 2 ± 32 Significant	21 6 ± 16 +5 1 ± 25 Significant	18 4 ± 12 +1 0 ± 23 Significant	18 9 ± 18 +2 4 ± 27 Significant	
11 A M.	25 0 ± ·30 Difference from air temperature	29 2 ± 25 +4 2 ± 39 Significant	29 1 ± ·30 +4 1 ± 42 Significant	26 7 ± 20 +1 7 ± 36 Significant	26 5 ± 15 +1 5 ± 33 Significant	The leaves remain warmer throughout the day than the air but the inner tissue shows air temperature in the evening
1 P M	26 0 ± 41 Difference from air temperature	31 9 ± ·30 +5 9 ± 50 Significant	30 8 ± ·35 +4·8 ± 54 Significant	28 2 ± 20 +2 2 ± 45 Significant	28 0 ± 21 +2 0 ± 46 Significant	
3 P.M	26 7 ± ·45 Difference from air temperature	29 9 ± 40 +3 2 ± 60 Significant	29 7 ± 42 +3 0 ± 60 Significant	28 8 ± 25 +2 1 ± 51 Significant	28 5 ± 23 +1 8 ± 55 Significant	
5 P M.	16·8 ± 37 Difference from air temperature	20 6 ± 26 +3 8 ± ·45 Significant	20 4 ± ·23 +3 6 ± 43 Significant	19 1 ± ·16 +2 3 ± 40 Significant	19 4 ± 12 +2 6 ± 38 Significant	
7 P M.	14 2 ± ·40 Difference from air temperature	16 0 ± 40 +1 8 ± ·57 Significant	15 9 ± ·30 +1·7 ± 5 Significant	15 0 ± ·15 + 8 ± 42 Insignificant	15 1 ± 12 + 9 ± 41 Insignificant	

air After sunrise at 7–30 A M the temperature of leaves begins to rise rapidly. The temperatures of upper and lower surfaces continue to rise till 1 P.M., afterwards it falls slowly At 7 P M they are warmer than the air by about 1 5° C. The temperature of the inner tissue remains almost constant after 9 A M but at 7 P M. they show negligible difference from the air temperature.

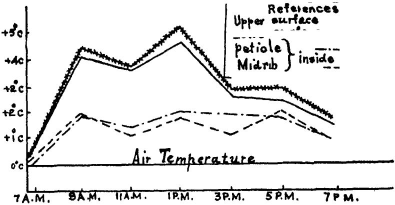

FIG 5 Monthly mean departures of leaf temperatures of irrigated 4F Cotton Plants from air during November at different periods of the day

IV (B) Leaf temperatures and soil moisture

It has been observed that the amount of water available in the soil has a marked influence on the temperature of leaves To study the effect of moisture content, tempearture determinations were made on leaves of 4F cotton crop grown in a field which received no irrigation after sowing But as some rains fell in July and August the crop was as good as the irrigated one

Sometimes in September, however, the unirrigated crop showed signs of wilting Determinations of the moisture contents of the soil in the irrigated and unirrigated plots were made from time to time and are given in Table VIII which shows that, as compared with the irrigated crop, the unirrigated crop was deficient in soil moisture

TABLE VIII

Percentage of soil moisture at various depths of irrigated and unirrigated fields during different months

Month	Nature of the field	Depth	Percentage of soil moisture	
ugust 1931	Irrigated	1st ft	9 39	There was about 4 31 inches of rainfall
		2nd ft	12 04	
		3rd ft	11 77	
	Unirrigated	1st ft	9 39	
		2nd ft	11 72	
		3rd ft	10 86	
ptember 1931	Irrigated	1st ft	11·92	Samples for moisture determination were always taken 5–6 days after the last irrigation during August, September and October but 8–10 days in November
		2nd ft	12 30	
		3rd ft	13 04	
	Unirrigated	1st ft	1 09	
		2nd ft	5 72	
		3rd ft	8 25	
tober 1931	Irrigated	1st ft	10 27	
		2nd ft	11 38	
		3rd ft	12 21	
	Unirrigated	1st ft	94	
		2nd ft	4 59	
		3rd ft	6 39	
vember 1931	irrigated	1st ft	14 74	
		2nd ft	15 81	
		3rd ft	16 67	
	Unirrigated	1st ft	74	
		2nd ft	4 71	
		3rd ft	6 27	

Temperature of Unirrigated Cotton

September 1931 —The temperature of leaves was measured after every two hours The data obtained are given in Table IX and Fig 6 It will be seen that in the morning at 6 A M leaves show air temperature. The temperature of leaves afterwards begins to rise till the maximum value is recorded at 2 P M when leaves show a departure of about +4° C and inner tissue of +2° C to +3° C from the air temperature Afterwards the leaf temperature continues to fall but still remains higher than that of the air till 6 P M when the temperature of the leaves and the air are the same This condition is maintained up to daybreak The inner tissue, however, shows a spasmodic rise and fall throughout the night. It is noteworthy that leaves of the irrigated crop on the other hand have a lower temperature than the air from 12 to 6 P M by about $-2°$ C to $-3°$ C (Table I, Fig 1)

TABLE IX

Monthly mean departures of leaf temperatures (columns 3–5) *from air (column* 2) *during September* 1931 *(Unirrigated crop)*

" *Maximum flowering* " *Stage*

Time	Air temperature in degrees C	Upper surface	Lower surface	Inner tissue	
				Petiole	Midrib
1	2	3	4	5	
6 A M	23·5	+ 23	+ 23	+ ·35	+ 20
8 A M	27 1	+ 2 00	+ 1·80	+ 1 50	+ 1·3
10 A M	32 06	+3 00	+ 2 90	+ 2 09	+ 1 90
12 Noon	34 77	+ 3 35	+ 3 00	+ 1·90	+ 1·80
2 P M	37 89	+ 4 43	+ 4 61	+ 2 99	+ 2·32
4 P M	35 54	+ 2 49	+ 3 15	+ 81	– 24
6 P M	31 92	+ 5	+ ·25	+ 50	+ 00
8 P M	27 8	– 9	+ 81	+ 1 2	+ ·81
10 P M	27 11	– 51	+ 21	+ ·24	+ 24
12 Midnight	27 93	– 63	– ·30	+ 1·92	+ 2·66
2 A M	26 31	+ 19	+ 38	+ 1·00	+ 2·59
4 A M.	25 98	+ 61	+ 33	+ 00	+ ·20
6 A M	24·42	+ 91	– 05	+ 67	+ 25

TABLE IX

Comparison of mean departures of leaf temperatures from air on September 11, 1931

" Unirrigated crop "

Hours of observation	Mean Temperature of air in °C	Mean Temperature of Upper Surface in °C.	Mean Temperature of Lower Surface in °C	Inner tissue		Remarks
				Mean Temperature of Petiole in °C	Mean Temperature of Midrib in °C	
6 A M	24·7 ± ·25 Difference from air temperature	25·0 ± ·15 + ·3 ± ·29 Insignificant	24·9 ± ·18 + ·2 ± ·30 Insignificant	25·0 ± ·13 + ·3 ± ·28 Insignificant	24·9 ± ·16 + ·2 ± ·29 Insignificant	In the morning and evening leaves show air temperature, but remain considerably and significantly warmer than the air in the fore and afternoon by about 2° C to 5 °C
8 A M	29·4 ± ·32 Difference from air temperature	32·3 ± ·16 +2·9 ± ·36 Significant	31·4 ± ·20 +2·0 ± ·37 Significant	31·1 ± ·12 +1·7 ± ·34 Significant	31·0 ± ·11 +1·6 ± ·33 Significant	
10 A M	35·3 ± ·40 Difference from air temperature	38·4 ± ·20 +3·1 ± ·44 Significant	38·2 ± ·20 +2·9 ± ·44 Significant	37·8 ± ·16 +2·5 ± ·43 Significant	37·5 ± ·15 +2·2 ± ·42 Significant	
12 Noon	38·7 ± ·35 Difference from air temperature	42·3 ± ·25 +3·6 ± ·43 Significant	42·2 ± ·15 +3·5 ± ·38 Significant	40·9 ± ·20 +2·2 ± ·40 Significant	40·8 ± ·20 +2·1 ± ·40 Significant	
2 P M.	39·4 ± ·45 Difference from air temperature	44·6 ± ·50 +5·2 ± ·67 Significant	44·9 ± ·45 +5·5 ± ·63 Significant	42·9 ± ·35 +3·5 ± ·57 Significant	42·7 ± ·30 +3·3 ± ·54 Significant	
4 P M.	36·1 ± ·40 Difference from air temperature	38·3 ± ·25 +2·2 ± ·47 Significant	38·8 ± ·25 +2·7 ± ·44 Significant	36·6 ± ·21 + ·5 ± ·45 Insignificant	36·2 ± ·15 + ·1 ± ·45 Insignificant	
6 P.M	31·4 ± ·42 Difference from air temperature	31·8 ± ·30 + ·4 ± ·5 Insignificant	31·7 ± ·40 + ·3 ± ·56 Insignificant	31·5 ± ·30 + ·1 ± ·5 Insignificant	31·3 ± ·25 − ·1 ± ·48 Insignificant	
8 P.M.	29·6 ± ·30 Difference from air temperature	29·0 ± ·15 − ·6 ± ·33 Insignificant	29·2 ± ·20 − ·4 ± ·36 Insignificant	29·7 ± ·16 + ·1 ± ·34 Insignificant	29·9 ± ·12 + ·3 ± ·32 Insignificant	

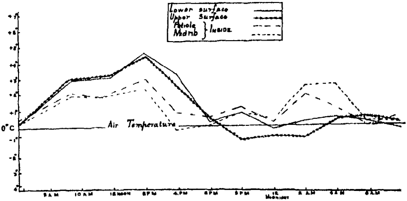

Fig. 6 Monthly mean departures of leaf temperatures of unirrigated 4F Cotton Plants from air during September at different periods of the day

October 1931 (*1st half*) —At 6 A M the temperature of the plants is slightly lower than air temperatures (Table X, Fig 8) After 6 A M there is a rapid rise of temperature in all parts of the leaves and the maxima is reached at 10 A M At this time, upper surface, lower surface, petiole and the

TABLE X

Monthly mean departures of leaf temperatures (columns 3-5) from air (column 2) during October 1931 (1st half) (Unirrigated crop)
" Stray boll picking " Stage

Time	Air temperature in degrees C	Upper surface	Lower surface	Inner tissue	
				Petiole	Midrib
1	2	3	4	5	
6 A M	23 71	− 1 37	+ 25	− 1 08	− 1·53
8 A M	30 5	+ 3 46	+ 3 14	+ 1·35	+ 1 72
10 A M	33 34	+ 6 04	+ 4 15	+ 2 87	+ 2 82
12 Noon	38 29	+ 5 95	+ 3 50	+ 1·41	+ ·95
2 P M	39 30	+ 3 92	+ 2·90	+ 2 17	+ 2 03
4 P M	35 23	+ 1 89	+ 1 22	+ ·52	+ ·51
6 P M	28 72	+ ·34	− ·77	+ ·14	− ·08
8 P M	22 12	+ 1·15	+ ·73	+ 1·29	+ 1·07

TABLE X

Comparison of mean departures of leaf temperatures from air on October 8, 1931

" Unirrigated crop "

Hours of observation	Mean Temperature of air in °C	Mean Temperature of Lower Surface in °C	Mean Temperature of Upper Surface in °C	Inner tissue		Remarks
				Mean Temperature of Petiole in °C	Mean Temperature of Midrib in °C	
6 A M	24 6± 20 Difference from air temperature	23 0± 15 −1 6± 25 Significant	24 0± 13 − 6± 23 Insignificant	23 1± 16 1 5± 25 Significant	23 2± 15 −1 4± 25 Significant	In the morning the leaves are comparatively cooler than the air, but remain warmer from 8 A M to 4 P M and acquire air temperature again in the evening
8 A M	30 8± 42 Difference from air temperature	34 9± 25 +4 1± 48 Significant	34 8± 30 +4 0± 51 Significant	32 3± 18 +1 5± 42 Significant	32 8± 25 +2 0± 48 Significant	
10 A M	34 2± 50 Difference from air temperature	41 4± 52 +7 2± 7 Significant	39 6± 40 +5 4± 64 Significant	37 3± 20 +3 1± 53 Significant	37 2± 25 +3 0± 55 Significant	
12 Noon	37 9± 38 Difference from air temperature	42 5± 40 +4 6± 55 Significant	41·9± 35 +4 0± 51 Significant	39 7± 20 +1 8± 42 Significant	39 5± 18 +1 6± 42 Significant	
2 P M	40·0± 40 Difference from air temperature	43 5±·30 +3 5± 5 Significant	42·4± 25 +2 4± 47 Significant	42 1± 20 +2 1± 44 Significant	42 3± 15 +2 3± 42 Significant	
4 P M	34·5± 30 Difference from air temperature	36 8± 40 +2 3± 5 Significant	36 5± 32 +2 0± 43 Significant	35 2± 20 + 7± 35 Insignificant	35 4± 20 + 9± 35 Insignificant	
6 P M	29 2±·15 Difference from air temperature	29 7± 20 + 5± 25 Insignificant	29 1± 15 − 1± 21 Insignificant	29 4± 12 + 2± 19 Insignificant	29 5± 15 + 3± 21 Insignificant	
8 P M	21 4± 30 Difference from air temperature	22 0± 15 + 6± 33 Insignificant	22 1± 20 + 7± 35 Insignificant	22 2± 15 + 8± 33 Insignificant	22 1± 13 + 7± 32 Insignificant	

midrib showed a departure of +6·04° C, +4 15° C, +2 87° C. and +2·82° C. respectively From 10 A M onwards there is a gradual fall till 6 P.M, when the plants acquire air temperature The inner tissue shows a slight rise of temperature again at 2 P M At 8 P M again the plants show higher temperature than the air by about 1° C

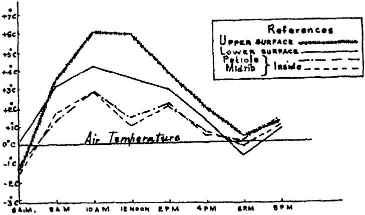

FIG 7 Monthly mean departures of leaf temperatures of unirrigated 4F Cotton Plants from air during October (I part) at different periods of the day

October 1931 (*2nd half*) *and November* 1931 —The data obtained is compiled in Tables XI and XII and Figs 8 and 9 respectively The

TABLE XI

Monthly mean departures of leaf temperatures (*columns* 3–5) *from air* (*column* 2) *during October* 1931 (*2nd half*) (*Unirrigated crop*)

" *Stray boll picking* " *Stage*

Time	Air temperature in degrees C	Upper surface	Lower surface	Inner tissue	
				Petiole	Midrib
1	2	3	4	5	
7 A M	13·6	+ ·55	− ·03	− ·70	− 1·36
9 A M	22·48	+ 3·74	+ 3·01	+ 2·6	+ 2·55
11 A M	29·52	+ 2·81	+ 2·23	+ ·11	+ ·73
1 P M	32·62	+ 3·37	+ 2·36	+ 1·71	+ 1·51
3 P M	30·46	+ 1·13	+ ·60	+ ·47	+ ·90
5 P M	23·70	+ 2·22	+ 1·53	+ 2·12	+ 1·48
7 P M	13·37	+ ·72	+ ·03	+ 1·38	+ 1·22

TABLE XI

Comparison of mean departures of leaf temperatures from air on October 23, 1931

" Unirrigated crop "

Hours of observation	Mean Temperature of air in °C	Mean Temperature of Upper Surface in °C	Mean Temperature of Lower Surface in °C	Inner tissue		Remarks
				Mean Temperature of Petiole in °C	Mean Temperature of Midrib in °C	
7 A M	13 0± 40 Difference from air temperature	13 7± 35 + 7± 53 Insignificant	13 4± 30 + 4± 5 Insignificant	13 2± 20 + 2± 44 Insignificant	12 2± 10 - 8± 53 Insignificant	The leaves in this month show very erratic behaviour
9 A M	20·4± 45 Difference from air temperature	24 6±·40 +4 2± 00 Significant	24 8± 25 +4 4± 51 Significant	23 4± 15 +3 0± 47 Significant	23 4± 10 +3 0± 48 Significant	
11 A M	26 7± 35 Difference from air temperature	29 9± 30 +3 2± 46 Significant	29 4± 35 +2·7± 49 Significant	27 2± 18 + 5± 39 Insignificant	27 9± 14 +1 2± 37 Significant	
1 P M	27 4± 25 Difference from air temperature	30·9±·30 +3·5±·39 Significant	30 1± 40 +2 7± 47 Significant	29 4± 2 +2 0± 32 Significant	29 2± 30 +1 8± 30 Significant	
3 P M	27·8± 32 Difference from air temperature	29 6± 20 +1 8± 37 Significant	28 8± 20 +1 0± 37 Insignificant	28 6± 16 + 8± 35 Insignificant	28·8± 15 +1 0± 35 Insignificant	
5 P M.	22 0± 18 Difference from air temperature	23·9± 30 +1·9± 35 Significant	23 9± 20 +1 9± 27 Significant	23 5± 16 +1 5± 24 Significant	23 8± 18 +1·8± 25 Significant	
7 P M	14·1± 40 Difference from air temperature	14·9± 30 + 8± 5 Insignificant	14·5± 35 + 4± 53 Insignificant	15 0± 25 + 9± 47 Insignificant	14 9± 29 + 8± 49 Insignificant	

leaves show air temperature at 7 A M except the inner tissue during October 2nd half after which there is a rapid rise till maximum is reached at 9 A M From this time onwards temperature of the plant rises and falls till 7 P M, when the plants are warmer than the air by about 1°C to 2°C, but the inner tissue during November becomes cooler at 5 P.M. and remains so till 7 P.M

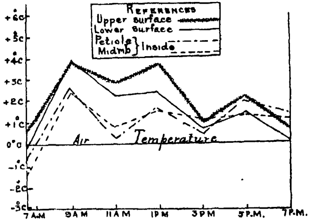

Fig 8. Monthly mean departures of leaf temperatures of unirrigated 4F Cotton Plants from air during October (II part) at different periods of the day.

TABLE XII

Monthly mean departures of leaf temperatures (columns 3 5) *from air* (column 2) *during November* 1931 (*Unirrigated crop*)

" *Peak of boll picking* " *Stage*

Time	Air temperature in degrees C	Upper surface	Lower surface	Inner tissue	
				Petiole	Midrib
1	2	3	4	5	
7 A M	10 92	− ·42	− 4 5	−1 8	− 16
9 A M	21 19	+3 43	+3 02	+2 92	+2 72
11 A M	27 98	+3 41	+3 14	+1 01	+1 14
1 P M	32 89	+2 80	+2 77	+ 99	+ ·4
3 P M	30·90	+2 95	+3 09	+1 27	+1 19
5 P M	20·60	+3 21	+2 53	− ·72	− ·41
7 P M	15·71	+2 06	+ 94	− 72	− 82

TABLE XII

Comparison of mean departures of leaf temperatures from air on November 15 during 1931 *"Unirrigated crop"*

Hours of observation	Mean Temperature of air in °C	Mean Temperature of Upper Surface in °C	Mean Temperature of Lower Surface in °C	Inner tissue		Remarks
				Mean Temperature of Petiole in °C	Mean Temperature of Midrib in °C	
7 A M	12 2 ± 30 Difference from air temperature	12 0 ± 20 – 2 ± 36 Insignificant	11 8 ± 15 4 ± 33 Insignificant	12 0 ± 15 – 2 ± 33 Insignificant	12 0 ± 15 – 2 ± 33 Insignificant	In the morning and evening the leaves have temperature of the air, but are warmer significantly than the air from 9 A M to 3 P M
9 A M	18 4 ± 40 Difference from air temperature	22 2 ± 25 +3 8 ± 47 Significant	22 4 ± 18 +4 0 ± 43 Significant	21 8 ± 16 +3 4 ± ·43 Significant	21 5 ± 12 +3 1 ± 41 Significant	
11 A M	28 1 ± 46 Difference from air temperature	31 8 ± 37 +3 7 ± 59 Significant	31 6 ± 28 +3 5 ± 54 Significant	30 0 ± 11 +1 9 ± 47 Significant	29 8 ± 10 +1 7 ± 47 Significant	
1 P M	32 4 ± 20 Difference from air temperature	35 7 ± 15 +3 3 ± 25 Significant	35 5 ± 16 +3 1 ± 25 Significant	33 6 ± 11 +1 2 ± 22 Significant	33 4 ± 10 + 8 ± 22 Significant	
3 P M	28 6 ± 40 Difference from air temperature	31 7 ± 25 +3 1 ± 47 Significant	31 8 ± 16 +3 2 ± 43 Significant	30 1 ± 20 +1 5 ± 44 Significant	30 2 ± 16 +1·6 ± 43 Significant	
5 P M	18 8 ± 35 Difference from air temperature	21 3 ± 20 +2·5 ± 4 Significant	21 5 ± 22 +2 7 ± 41 Significant	18 0 ± 16 – 8 ± 38 Insignificant	18 1 ± 16 7 ± 38 Insignificant	
7 P M.	15·4 ± 40 Difference from air temperature	17 8 ± ·15 +2 4 ± 42 Significant	10 1 ± 43 + 7 ± 43 Insignificant	14 6 ± 12 – 8 ± 41 Insignificant	14 8 ± 13 – 6 ± 42 Insignificant	

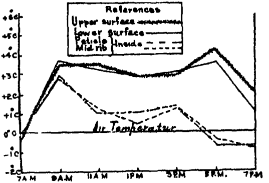

FIG. 9 Monthly mean departures of leaf temperatures of unirrigated 4F Cotton Plants from air during November at different periods of the day.

V. (C) *Moisture content of the leaves during growth period of the plant*

The amount of water present in cotton leaves was determined after an interval of two hours from 6 A M to 8 P M once a week during the months of August–November The leaves were dried to a constant weight in an electric oven Average results obtained for the irrigated and unirrigated crop are given in Table XIII and Figs 10 and 11

Reference to these tables and figures shows how the amount of moisture in the leaves of irrigated crop varies in the course of a day In August, the leaves have 82 per cent moisture in the morning Then it begins to decrease with the advance of the day till at 2 P M the leaves are left with only 61 per cent of moisture After 2 P.M moisture content of the leaves again begins to increase At 8 P M it goes upto 73 per cent In September, the percentages of moisture in leaves is reduced by about 5 per cent as compared with August Correspondingly the extent of variability is affected Similarly in October and November there is a marked fall in the percentage of moisture in the leaves and degree of variability With regard to the unirrigated crop the leaves during the course of the day and during different months from September to November always showed about 5 to 10 per cent less moisture (Table XIII, Fig 11)

Variability of moisture was also significantly less The leaves got wilted daily after 10 A M and remained so till 4 P M It may be pointed out that the rate of transpiration of leaves varies considerably in different months and under different conditions of soil moisture

TABLE XIII

Percentage moisture in the leaves of 4F cotton plants during different months of the growing season at different times of the day in 1931

(*On dry weight basis*)

Kind of crop	Month	Time															Age of Plants in days
		6 A.M	7 A M	8 A.M	9 A.M	10 A.M	11 A M.	12 NOON	1 P M	2 P M	3 P M	4 P M	5 P M	6 P M.	7 P M	8 P M	
Irri-gated	Aug	82 03	.	80·54		74 87		69 36		60 59		63 08		72 42		72 93	90
	Sept	78 12		75 47		75 40		73 10		63 83		65 67		75 38		76 58	120
	Oct	75 03		73·63		72 47		70 02		68 89		68 32		72 16		73 64	150
	Nov		73 90		72 50		70 22		70 80		72 60		72 30		75 20		180
Unirri-gated	Sept.	74 89	.	71 62		69 27		67 10		66 72		67 81		69 24		70 79	120
	Oct	.	72 22		70 01	.	66 64		65 43		68 71		71 66		71 98		130
	Nov.		69 39		67 51		66 66		66 31		67 40		67 84		69 87		180

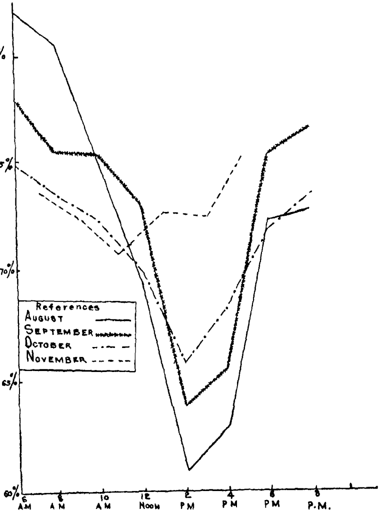

Fig 10. Variation in the amount of moisture in the leaves of irrigated 4F Cotton Plants during various months at different periods in the day.

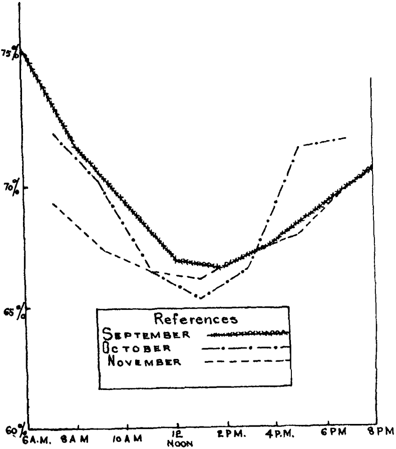

FIG. 11. Variation in the amount of moisture in the leaves of unirrigated 4F Cotton Plants during various months at different periods in the day.

VI (D) *Temperature and age of leaves*

Usually plants behave like cold-blooded animals whose temperature varies with the medium in which they live This, however, is true within certain limits The temperature regulatory power of the leaves diminishes with age as is indicated by Table XIV

TABLE XIV.

Mean temperature departures of old and young leaves from air temperature at different periods of the day during September and October 1931

Average of 50 determinations

Time	Air Temperature in °C	Nature of Leaves	Mean Temperature of Upper Surface in °C	Mean Temperature of Lower Surface in °C	Inner tissue		Remarks
					Mean Temperature of Petiole in °C	Mean Temperature of Midrib in °C	
7 A M	21·2	Old	+1·6±·30	+1·4±·20	+1·0±·20	+1·1±·35	Old leaves were 40–45 days old and young leaves were 25–30 days old
		Young	+·5±·25	+·3±·28	+·4±·15	+·3±·17	
	Difference (Old − Young)		+1·1±·39	+1·1±·34	+·6±·25	+·8±·38	
			Insignificant	Insignificant	Insignificant	Insignificant	
1 P M	31·0	Old	+·5±·15	+·3±·10	−0·1±·16	−0·3±·12	
		Young	−1·7±·20	1·8±·09	−2·0±·12	−2·3±·10	
	Difference (Old − Young)		+2·2±·25	+2·1±·13	+1·9±·20	+2·0±·15	
			Significant	Significant	Significant	Significant	
7 P M	28·4	Old	+·2±·15	+·1±·12	+·4±·16	+·1±·18	
		Young	+·1±·10	+0·0±·13	−·2±·16	−·4±·20	
	Difference (Old − Young)		+·1±·18	+·1±·17	+·6±·26	+·5±·27	
			Insignificant	Insignificant	Insignificant	Insignificant	

50 determinations were made on the temperature of young and old leaves at different periods of the day The results obtained show that the leaves when young are able to adjust themselves readily with the air temperature as it fluctuates In the afternoon when air temperature rises, temperature of young leaves never rises above the air, but on the other hand old leaves get warmed up and show a higher temperature Perhaps, this is due to the fact that the young leaves have greater moisture content and are thus better able to conduct energy The old leaves have been found to contain less moisture, and consequently remain warmer than the air

In the morning and evening mean temperature differences of the old and young leaves are statistically insignificant but at 1 P M the old leaves are warmer as compared with young leaves by about 2·0°C. and the difference is highly significant

VII (E) Temperature of wilted leaves

In this connection measurements of temperature were made at 1 P M. in September and October 1930 The data given in Table XV show that their temperature was 3° to 4° C higher than that of the air. In some cases the difference was found to be as high as 10° C.

TABLE XV

Mean temperature departures of normal and wilted leaves at 1 P M during September and October 1930

Average of 51 determinations

Nature of leaves	Air temperature in degrees C	Upper surface	Lower surface	Inner tissue	
				Petiole	Midrib
1	2	3	4	5	
Normal	31 3	+1 5 ± 2	+1 1 ± 30	−1 1 ± 25	−1 2 ± ·20
Wilted	31 6	+3 9 ± 15	+2 9 ± 20	+3 4 ± 10	+2 0 ± 30
Difference (Wilted − Normal)		+2 1 ± 25 Significant	+1 80 ± 36 Significant	+4 5 ± 47 Significant	+3 2 ± 36 Significant

Wilted leaves show higher temperature than normal leaves and the mean difference is statistically found to be highly significant

VIII *Discussion of the results*

(1) The main data are presented in Tables I to XII and Figs 1 to 9 It will be observed that leaves of the cotton plant behave differently regarding their temperature during different months In the hot months of July, August and September as shown in Figs 1, 1 (*a*) and 2, there is a rise of leaf temperature from 6 A M to 8 A M or 10 A M and afterwards a fall occurs The fall is evidently due to the cooling of the plant as a result of transpiration, which increases as the day advances, because greater solar radiation promotes transpiration under certain conditions During the middle of the day, when air temperature is at its maximum and the solar energy incident on the leaves is correspondingly high, leaves of the irrigated crop show a lower temperature by − 2° C to − 3° C due to active transpiration Some preliminary experiments on the rate of transpiration in cottons show that it is greater during the middle of the day than in the morning and evening

In the case of the unirrigated crop, it is found that in September and October (1st half) Figs 6 and 7, the leaves show air temperature in the morning when the atmosphere is cool and transpiration is very little But as it gets hotter the leaf temperature rises above that of the air and it is 4° C. higher between 12 noon and 3 P.M In this respect the unirrigated crop shows a marked difference from the irrigated crop where the plants have a lower temperature than that of the air during these hours (Figs. 2 & 3)

The explanation seems to be that on account of shortage of moisture in the soil and leaves in the unirrigated crop, transpiration is reduced and sufficient cooling effect is not produced

As the weather becomes colder, the differences of monthly mean departures of the two crops become less striking This is perhaps due to the fact that moisture content of the leaves of irrigated crop also is depleted with advance in age as shown in Table XIII and also partly because temperature of the soil falls (Table XVIII) and the root absorption is reduced This has been shown by results of unpublished experiments of the senior author on "Effect of various temperatures on root-absorption in cotton".

(2) Table XVI Appendix A indicates a very interesting behaviour of the leaves during different months In the case of unirrigated crop there is a successive backward shift of the maxima of the mean departure in temperatures from September to November In September the maxima occurs at 2 P M while in October it is at 11 A M or 9 A M, and in November it comes at 9 A M

Reverse is the case in the irrigated crop The shift of the maxima goes forward (Table XVI Appendix A), *i e*, from 8 A M in August to 10 A M in September and 1st part of October It comes at 3 P M in October (2nd half). There is then a backward shift in November when it comes at 1 P M

In seeking an explanation for this, it has to be borne in mind that leaf temperature is correlated with transpiration, which depends upon air humidity, leaf moisture, soil moisture and root-absorption

In August, the average humidity (Table XIX Appendix A) during the day is high The transpiration, therefore, will be low and this causes a rise in the leaf temperature earlier But in September and October, humidity is lower and thus the relative transpiration is greater than in August; consequently the leaves attain maximum temperature later In November with increase in humidity accompanied by shortage of soil moisture, etc., the relative transpiration decreases again and the maximum temperature is attained earlier by the leaves

In the case of unirrigated crop as is shown by Table XIII, Fig. 11, the soil moisture decreases from September to November along with leaf moisture. For this reason a decrease of transpiration occurs and the plants tend to attain the maximum temperature earlier.

(3) Statistical studies made on the coefficient of correlationn between surface temperatures and temperatures of the inner tissue show that in the

case of the irrigated crop there is a very high positive correlation which remains almost constant (Table XVII Appendix A) from August to October (1st half). The correlation co-efficient becomes very low during 2nd half of October, perhaps due to the upset of water balance in the plants on account of low soil temperatures (Table XVIII Appendix A) When the plants adjust themselves to low water supply from the roots, the coefficient of correlation again becomes very high in November

The coefficient of correlation is almost constant from September to November in the case of the unirrigated crop Probably on account of the adjustment of the plants to low water contents, tendency for variation is checked

(4) The rise of temperature of wilted leaves above that of the air during September and October is probably due to shortage of moisture in the leaves and soil In this connection the findings of Molisch (1925) and others on the conversion of starch into sugars in wilting leaves may be of considerable significance Some preliminary work of the authors of this paper shows that the respiratory activity of wilted leaves is less than that of turgid leaves This might be due to the accumulation of sugars and inadequate moisture content in the wilted leaves Déhéram and Manquene (1886) as well as Iljin (1922) and Dastur (1925) have shown how greatly the rate of photosynthesis of leaves is affected by their water content This points out that the leaves of the crop which become flaccid or wilted due to inadequate soil moisture cannot carry on metabolic functions properly Moreover Iljin (1922) also investigated that leaves which have once become flaccid or wilted and have regained turgidity and normal appearance after adequate supply of water is given, do not attain their original photosynthetic activity It follows from these experiments that if a plant gets inadequate supply of water it has not only higher temperatures than the air, but also becomes less active for the performance of metabolic functions properly Nutritive processes, therefore, are liable to receive a set-back as a result of shortage of soil moisture and the recovery from this disability may not take place to the extent of resuming normal condition This finding has an important bearing on the irrigation of American cottons in canal colonies

IX Summary

(1) The paper deals with the determination of temperatures of 4F American cotton plant at Lyallpur Temperature was taken by means of a thermo-couple apparatus

(2) Readings were taken after every 2 hours during day and night in August and September and only during the day in July, October and November. The data are given in the form of departures from the air

(3) It has been shown that the temperature of the cotton plant is never constant It changes according to the temperature of the surrounding air A slight change in the temperature of the air brings about a corresponding increase or decrease in the temperature of leaves. From June to September in the morning and evening the plants show air temperature In the afternoon when the atmosphere is hot, plants are cooler by about 2° C. to 3° C In October and November however, the plants usually remain warmer than the air and this is perhaps associated with decreasing moisture content of the leaves and consequent decrease of transpiration At night time, the plants had air temperature The temperature of the plant is not a constant quantity Unlike warm blooded animals which have a definite limit of body heat in healthy conditions, plants warm up or cool down just as the temperature of the surrounding air rises or falls Plant is like a cold blooded organism, whose temperature varies with the medium in which it lives

(4) Soil moisture has been found to exercise a marked influence on the temperature of the leaves The plants of the unirrigated crop, which were all the time suffering from shortage of soil moisture, showed a higher temperatures by about 4° C to 5° C during September in the afternoon Irrigated plants at this time were cooler bv about 2° C to 3° C

(5) On the same plant the temperature of young leaves is found to be lower and that of the old leaves higher than that of the air at 1 P M, but in the morning and evening there is no significant difference

(6) Wilted leaves have higher temperatures than that of healthy turgid leaves by 3° C to 4° C In some cases the difference of about 10° C was observed

(7) The leaves of the unirrigated crop were found to have lower moisture content as compared with irrigated crop The amount of moisture decreases with increase in age The figures of variability in moisture content during the day are 22, 15 and 10 in August, September and November respectively The leaves of the unirrigated crop show less variation in moisture content

(8) A positive correlation has been found between leaf surface temperatures and that of the inner tissue In irrigated cotton it varies between $+0\ 94 \pm \cdot 032$ and $+0\ 78 \pm 0\ 15$ For unirrigated crop it is $+0 \cdot 77 \pm 0 \cdot 15$

APPENDIX A

TABLE XVI

Shift of the maxima of the mean departures of leaf temperatures from air during different months in 1931

Month	Temperature of	Time at which maxima occurs
	Irrigated plot	
August	Surface	8 A M
	Inner tissue	8 A M
September	Surface	10 A M
	Inner tissue	10 A M
October (1st half)	Surface	10 A M
	Inner tissue	10 A M
October (2nd half)	Surface	3 P M
	Inner tissue	9 A M
November	Surface	1 P M
	Inner tissue	1 P M
	Unirrigated plot	
September	Surface	2 P M
	Inner tissue	2 P M
October (1st half)	Surface	11 A M
	Inner tissue	11 A M
October (2nd half)	Surface	9 A M
	Inner tissue	9 A M
November	Surface	9 A M
	Inner tissue	9 A M

TABLE XVII

Coefficient of correlation between surface and inner tissue temperatures during different months in 1931

Month	Irrigated plot	Unirrigated plot
August	+ 94 ± ·032	..
September	+ 75 ± 12	+ ·77 ± ·15
October (1st half)	+ 604 ± 26	+ 84 ± 09
October (2nd half)	+ 26 ± 06	+ ·61 ± ·24
November	+ 78 ± 15	+ ·69 ± 19

TABLE XVIII

Average soil temperature during different months in 1931 *at* 35 *cm depth*

Month	Soil temperature in degrees C.
August	34 05
September	30 88
October (1st half)	29 9
October (2nd half)	23 0
November	18 5

TABLE XIX

Average humidity during different months in 1931 *at* 8 *A M*

Month	Percentage humidity
August	73 8
September	65 3
October	66 0
November	69·0
December	75·0

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THE PHYSIOLOGY OF DIGESTION AND ABSORPTION IN THE CRAB *PARATELPHUSA (OZIOTELPHUSA) HYDRODROMUS* (HERBST).

By A Ramakrishna Reddy, B Sc (Hons)
(From the Department of Zoology, Annamalai University, Annamalainagar, S. India.)

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1 *Introduction*

The various aspects of digestion among Crustacea were studied extensively The most recent paper on the subject is that of C M Yonge (1924) Excepting for a few papers on the structure and mechanism of the gastric armature in Decapods, no aspect of digestion was ever studied in any Indian type In the present paper, the author proposes to deal with the physiology of digestion and absorption and *Paratelphusa* (*Oziotelphusa*) *hydrodromus* (Herbst) This is the common South Indian field crab which lives in deed burrows having a peculiarly oblique descent on the muddy banks of ponds and small canals It is often covered by patches of muddy colour and remains at the entrance of its burrow protruding its stalked eyes At one's approach it rapidly crawls away into its retreat

This has been selected for study on account of the ease with which it is obtained at all times and the convenience with which it is kept under observation, in the laboratory for long periods

2 *Material and Methods*

The crabs were collected in and around the University area and kept under observation in the laboratory Some of them were fixed as soon as they were collected from the field while others were fixed at different periods of starvation to study the extent of the period to which fat within the digestive gland can persist To study the passage of food in the digestive tract the animals were starved to begin with for a period of three days and then fed on bits of flesh stained with carmine and methylene blue and fixed at different intervals The preliminary starving forces the crabs to feed on the food stained with unpalatable dyes

In almost all cases the material was fixed in Bouin's fluid In the case of the digestive gland 30% alcohol containing 5% corrosive sublimate was used as a fixative In the case of animals which were fed on olive oil stained with Sudan III, Fleming's solution without acetic acid was used as fixative When the animals were fed on ferrum oxydatum saccharatum, they were fixed in 95% alcohol containing 5% ammonium sulphide

In order to section the heavily chitinised regions of the fore-gut, the material was decalcified for three or four days in 70% alcohol containing 2·5% nitric acid and then transferred to a 10% solution of soft soap in which it was kept for four days and embedded in the ordinary way

In almost all the cases sections were stained in Delafield's hæmatoxylin and eosin In a few cases Heidenhain's iron-hæmatoxylin was employed

In connection with the observations made on the peristalsis of the mid- and hind-guts, the apparatus suggested by Hogben and Hobson (1924) in their studies on internal secretions was adopted The mid-gut or the hind-gut was excised from the living animal and the two extremities were ligatured with silk By means of one end it is fixed in the bath of saline medium (in proportions by volume of 5/8 molar solutions NaCl 200, $MgCl_2$ 40, KCl 2, $CaCl_2$ 2, dextrose 3, with Na_2HPO_4 to P_H 7) The other end is connected with the writing lever Adrenaline and epinine in dilutions of 1/80,000 and 1/1,00,00,00 respectively were used for perfusing the isolated regions of the gut

3 *Alimentary Canal*

(*a*) *General description and histology*

The alimentary canal falls into three natural divisions —(i) The fore-gut, (ii) The mid-gut and (iii) The hind-gut

Fore-gut —The mouth is situated on the ventral side of the cephalic region between the mandibles and is bound in front by the fleshy labrum and behind by the metastoma It leads into the fore-gut which is lined throughout by a cuticle which is continuous with the exoskeleton around the mouth The fore-gut consists of three distinct parts --

(*1*) *Oesophagus* —The epithelium consists of cells of great length They are 85 μ in length in a crab with a carapace of 2·5 inches in breadth and are 3 μ in width External to the epithelial layer is a thin chitinous layer of 12 μ in thickness. This consists of an outer deeply staining layer and an inner structureless layer There is a distinct basement membrane beneath which is a layer of connective tissue This is composed of dense reticulate fibres with a number of small nuclei External to the layer of connective tissue is a layer of circular muscles—the constrictor muscles The dilator muscles pass through the connective tissue and are attached to the basement membrane.

Lying in the connective tissue are larger numbers of round glands termed the tegumentary glands (Fig 5) Each gland is globular and consists of numerous narrow conical cells The apex of each cell is directed inwards In the centre of each mass is a narrow cavity (*Cav* Fig 5) which is continued into the cavity of the œsophagus by means of an intra-cellular duct (*Int D* Fig 5) Each cell of the gland is provided with a distinct nucleus and stains deeply They have a diameter of 20 to 30 μ These glands are scattered through the connective tissue of the œsophageal wall and the labrum and the metastoma are also packed with them They are also present in the hind-gut

These glands were supposed to have a digestive function and were termed salivary or intestinal glands (Huet, 1883), (Vitzou, 1882) They secrete a sticky substance which entangles the food in the gut The secretion does not reveal the presence of any digestive enzyme As Yonge (1924) has pointed out their presence only in the fore-gut and hind-gut always in connection with chitin suggests the possibility of their rôle in the secretion and preservation of the chitinous lining

(2) *Cardiac fore-gut* —The œsophagus runs directly upwards and opens into the spacious cardiac fore-gut (*C* Fig 1) This is a large spherical sac whose chitinous lining is thickened at definite places to form a complicated arrangement of ossicles termed the gastric armature which will be described below At the posterior wall of the cardiac fore-gut is a ventral invagination termed the cardio-pyloric valve separating the cardiac chamber from the pyloric chamber

(3) *Pyloric fore-gut* -- The cardiac chamber passes downwards into the pyloric chamber (*Py* Fig 1) This is simple towards its anterior third In the posterior two-thirds its ventral wall is thickened to form two rounded lateral pouches the "ampoules pyloriques" of Mocquard (1883) These constitute the "gland filter" of Yonge (1924) Each ampulla is thrown into distinct longitudinal ridges beset with stiff setæ The two ampullæ meet in the mid-ventral line forming the inter-ampullary ridge (*I Amp* Fig 2) The ventro-lateral walls of the chamber are also thickened forming the supra-ampullary ridges (*S Amp* Fig 2) The approximation of the supra-ampullary ridges divides the pyloric chamber into a dorsal comparatively free region and a ventral portion (*V D* Fig 2) which is further subdivided into a left and a right portion by the presence of the inter-ampullary ridge Detailed account of the structure and mechanism of the gland filter is found in the works of Jordan (1904), Williams (1907) and Yonge (1924) The cardiac and pyloric chambers have the same histological details as the œsophagus. There is a columnar epithelium and the chitinous layer is thin

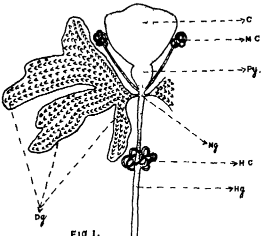

Fig 1.

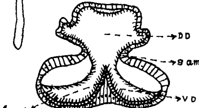

Fig 2

in places other than those occupied by the masticatory ossicles There is a distinct basement membrane, and a thin layer of connective tissue with circular and longitudinal muscles

Mid-gut—Posteriorly the pyloric chamber passes into the mid-gut From the upper side of the posterior end of the pyloric chamber six to seven flap-like structures or valves project into the mid-gut The views of Cuenot (1893), Mocquard (1883) and Huxley (1880) regarding the physiological significance of these structures are discussed elsewhere in this paper

From the anterior region of the mid-gut two cæca, the mid-gut cæca arise one from each side Each cæcum extends over the pyloric chamber and is pressed against the side of the cardiac chamber The digestive gland also opens into the mid-gut just behind the mid-gut cæca (Fig 1)

The mid-gut is the shortest portion of the alimentary canal and is about 12–13 mm in a full-grown crab (Fig 1) The epithelial cells (Fig 3) are columnar and are 50 μ in length with small nuclei They are provided with a striated border with a thickness of 1 to 2 μ Near the base of the epithelium there are the basal cells (*B C* Fig 3) of Frenzel (1885) with deeply staining large nuclei Beneath the epithelium is a basement membrane and beneath this is a layer of connective tissue with circular and longitudinal muscles

The mid-gut cæca have the same histology as the mid-gut

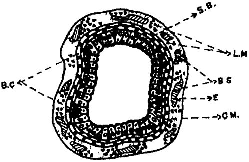

Fig 3

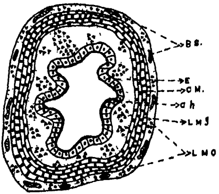

Fig 4

Hind-gut —The hind-gut is a long narrow tube which starts from the mid-gut and extends as far as the anus A long coiled cæcum (*H C* Fig 1), the hind-gut cæcum, is given off from the right side of the hind-gut before its entry into the abdomen. The hind-gut and hind-gut cæcum have columnar cells of 60 μ in length and have towards their inside a deeply staining thin chitinous layer (*Ch* Fig 4) which is produced into longitudinal ridges The chitinous layer is continuous with the exoskeleton at the anus The walls of the hind-gut as in the case of the œsophagus are packed with tegumental glands which are found in great profusion towards the anterior region of the hind-gut The circular and longitudinal musculature (*C M* and *L M I* and *L M O* Fig 4) is better developed in the hind-gut than in the mid-gut

(*b*) *Digestive gland*

Almost the entire ventral side of the anterior region of the cephalothorax is occupied by the paired digestive gland or hepatopancreas This is a yellowish brown lobulated structure Each half of the gland is composed of three main lobes There are three main ducts arising from them on each side corresponding to the three lobes These three finally end in fine blind tubules and the cavity of each tubule is in communication with the mid-gut as in the case of *Cancer*

In section (Fig 6) the tubules are bounded by connective tissue and are composed of two types of cells beneath a basement membrane (i) Ferment or secretory cells vary in height from 20 to 70 μ and 60 μ in width (*S C* Fig 6) Each cell contains small vacuoles and a darkly staining secretion Some of the cells are packed with secretion while others are found having discharged partly or completely their secretion into the lumen of the tubules

(ii) Absorption cells (*A C* Fig 6) are vacuolate and vary from 70 to-100 μ in length and 20 μ in width Fat globules are found within each cell The border of the cell in contact with the lumen of the tubule both in the case of ferment as well as absorption cells is striated

(*c*) *Ossicles of the fore-gut*

The ossicles of the fore-gut fall into two distinct sets (i) those of the cardiac chamber and (ii) those of the pyloric chamber The ossicles of each chamber can be further grouped into (i) main ossicles and (ii) supporting ossicles.

Main ossicles —The meso-cardiac ossicle (*M* Fig 12, A) is a triangular piece of sclerite transversely placed in the anterior region of the dorsal wall of the cardiac chamber The anterior end is ventrally inclined while the posterior broader end is not distinctly separated from the uro-cardiac ossicle (*U* Fig 12, A) and the ptero-cardiac ossicles (*Pt* Fig 12, A)

The uro-cardiac ossicle (*U* Fig 12, A) is attached to the hind end of the meso-cardiac ossicle and extends posteriorly along the dorso-median

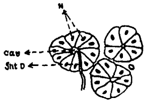

Fig 5

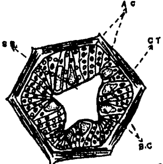

Fig 6

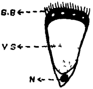

Fig 7

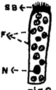

Fig.8

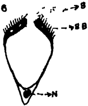

Fig 9.

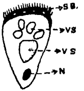

Fig 10

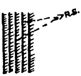

Fig 11

line Posteriorly, it inclines ventrally and gives articulation to the propyloric ossicle (*P P* Fig 12, C) Ventrally is the median tooth (*M D* Fig 12, A) which is differentiated into three regions. There is an anterior crescentic denticle and a broader posterior denticle with a concavity between them In front of the anterior denticle is a semi-circular depression in which a minute denticle is present

A pair of ptero-cardiac ossicles (*Pt* Fig 12, A) are attached to the meso-cardiac ossicle on either side by means of oblique hinges Their inner ends which are in contact with the meso-cardiac ossicle are broader while their outer ends are narrow The anterior gastric muscles are attached to the inner ends of the ptero-cardiac ossicles The outer ends of the ossicle articulate with the zygo-cardiac ossicles (*Z* Fig 12, B) by means of a ligament—the antero-lateral ligament of Pearson (1908) The posterior border

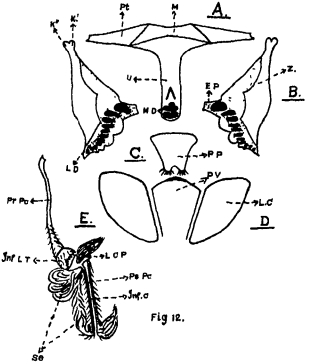

Fig 12.

of the ptero-cardiac ossicle is straight while the anterior has a somewhat curved margin

The pair of lateral zygo-cardiac ossicles (*Z* Fig 12, B) articulate with the outer ends of the ptero-cardiac ossicles on either side They pass posteriorly and exhibit a ventral inclination Each zygo-cardiac ossicle anteriorly is produced into two knob-like processes (*K'*, *K''* Fig 12, B) The inner process articulates with the outer end of the ptero-cardiac ossicle of its side The outer process is attached to the anterior end of the pre-pectinal ossicle one of the supporting ossicles described below of its side Anteriorly each zygo-cardiac ossicle is narrow, and rod-like and becomes broadened towards the hind end About the level of the median tooth the lateral teeth (*L D* Fig 12, B) are developed on them Posteriorly, the dorsal border is in connection with the cardio-pyloric valve (*P V*. Fig 12, D) and the exo-pyloric ossicles (*E P* Fig 12, B) The inner border of the ossicle is curved ventrally whereas the outer margin is bent inwards so that the ossicle exhibits a cavity towards the inside and a convexity towards the outside The outer border is folded forming a deep groove below the outer convexity Though the ossicle is thin, yet as a result of the complicated folding it gives a false impression of thickness

Each lateral tooth (*L D* Fig 12, B) of the zygo-cardiac ossicle carries eight to nine hard denticles separated by deep grooves. The denticles are differentiated into three to four definite regions. The nature of the denticles in each region differs from those in other regions.

The posterior border of the pro-pyloric (*P.P.* Fig 12, C) is rotated to the anterior side so that its position at rest resembles the position of the pro-pyloric ossicle of *Cancer pagurus* (Pearson, 1908) The exo-pyloric ossicles are attached to the posterior border and therefore displaced from the position described in *Gelasimus* (Reddy, 1934) This is provided with setæ and is depressed posteriorly In these depressions the cardio-pyloric constrictors are inserted The posterior end is bifurcated while the narrower anterior end is attached to the uro-cardiac ossicle

The pyloric ossicle is a broad dorso-median ossicle in the roof of the pyloric chamber Its anterior end is in contact with the pro-pyloric ossicle

The supporting ossicles —The pyloric supporting ossicles do not differ from those of *Cancer* described by Pearson (1908) The cardiac supporting ossicles however differ

The anterior ends of the pre-pectinal ossicles (*Pr Pc* Fig 12, E) articulate with the outer knob-like processes (*K'* and *K"* Fig 12, B) of the zygo-cardiac ossicles They closely follow the zygo-cardiac ossicles and gradually get broadened at their attachment with the pectinal ossicles The pectinal ossicles (*Inf L T* Fig 12, E) are cup-shaped and bear towards their inside the infra-lateral-cardiac teeth which are in a level with the lateral teeth on either side of the median tooth (*M D* Fig 12, A) Laterally, the pectinal ossicles are attached to the lateral cardio-pyloric ossicles (*L C P* Fig 12, E) and posteriorly to the infra-lateral cardiac and post-pectinal ossicles (*Inf s* , *Ps Pe* Fig 12, E) These are thickly beset with setæ The infra-lateral cardiac ossicles end in oval setose brushes towards the œsophagus on reaching the same level as the post-pectinal ossicles turn up and end in posteriorly directed long tufts of setæ (*Se* Fig. 12, E) which extend as far as the cardio-pyloric entrance

(*d*) ***Muscles of the fore-gut.***

The musculature falls into two types, *viz*, the extrinsic and intrinsic muscles.

Extrinsic musculature —The muscles in this system run from the ossicles of the gastric armature to the exo-skeleton The anterior gastric muscles extend between the inner ends of the ptero-cardiac ossicles and the anterior region of the carapace They are in the form of two distinct bands which diverge considerably anteriorly.

There are three bands of posterior gastric muscles The inner or the central band arises from the posterior region of the carapace and is inserted on the pyloric ossicle The outer bands also arise from the posterior region of the carapace and are inserted on the dorsal surface of the posterior ends of the zygo-cardiac ossicles.

There are two bands of cardiac levator muscles extending between the lateral walls of the cardiac chamber and the carapace The pyloric levator muscles extend between the lateral walls of the pyloric chamber and the posterior region of the carapace Two bands of cardiac depressor muscles extend between the ventro-lateral wall of the cardiac chamber and the anterior region of the sternum The pyloric depressor muscles proceed ventrally from the ventro-lateral wall of the pyloric chamber

Intrinsic musculature —In this case the muscles run between the ossicles of the armature within the fore-gut itself

The cardio-pyloric constrictors arise from the posterior border of the meso-cardiac ossicle and are inserted on the posterior border of the propyloric ossicle They are in three bands, the outer of which diverge slightly towards their insertion There are three pairs of lateral cardiac muscles The dorsal pair extends between the dorsal border of the zygo-cardiac ossicle and the upper region of the infra-cardiac ossicle and the pre-pectinal ossicle The central one extends between the upper region of the infra-cardiac ossicle and the pre-pectinal ossicle The ventral one runs from the lateral surface of the infra-lateral cardiac ossicle to the dorsal surface of the postero-lateral cardiac plate

The cardiac constrictors are formed by two sets of muscles the postero-inferior cardiac and antero-lateral cardiac muscles The postero-inferior cardiac muscles run between the two posterior ends of the infra-lateral cardiac ossicles The antero-lateral cardiac muscles arise as a bifurcated bend from the antero-lateral cardiac plate and are inserted on the anterior wall of the meso-cardiac ossicle just above the insertion of the cardio-pyloric constrictor muscles. The cardiac depressors and elevators are on either side of the cardiac constrictors

The pyloric constrictor muscles are constituted by a number of narrow bands between the post-pectinal and infra-lateral cardiac ossicles and the supporting ossicles in dorsal and lateral walls of the pyloric chamber (*e*) Modus Operandus *of the gastric armature*

Mocquard (1883), Pearson (1908) and Patwardhan (1934–35) have pointed out that the gastric armature is put into action mainly by the contraction of the anterior gastric muscles Huxley (1880) described the active movement as the result of contraction of both anterior as well as posterior gastric muscles But a study of the gastric armature of ***Paratelphusa*** and other South Indian Decapod Crustacea shows that the active movement is brought about mainly by the contraction of the posterior gastric muscles while the anterior gastric muscles and cardio-pyloric constrictors are chiefly concerned in the restoration of the armature to its position of rest

If the anterior gastric muscles were mainly responsible for the collision of the three teeth-bearing ossicles, namely, uro-cardiac and the two zygo-cardiac ossicles, as stated by Mocquard (1883), Pearson (1908) and Patwardhan (1934–35) the most important factor, *viz*, the pressing down of the uro-cardiac tooth to meet the colliding zygo-cardiac teeth could not be brought about on account of the reverted position of the propyloric ossicle It is only when the posterior border of the pro-pyloric ossicle is pulled backwards the uro-cardiac tooth is brought downwards This is made possible only by the contraction of the posterior gastric muscles. Their contraction results in pulling back the pro-pyloric ossicle which owing to the roof of the cardiac chamber presses down the uro-cardiac tooth to meet the zygo-cardiac teeth

Both the uro-cardiac and propyloric ossicles represent levers of the second order In the case of the uro-cardiac ossicle the fulcrum is situated at its attachment with the meso-cardiac ossicle while the power is applied at its posterior extremity just behind the uro-cardiac tooth by the anterior border of the pro-pyloric ossicle The power is the result of the contraction of the posterior gastric muscles and is transferred to that point by means of the exo-pyloric and pro-pyloric ossicles The work is performed in the region of the uro-cardiac teeth

In the case of the pro-pyloric ossicle the fulcrum is at the attachment of its anterior border with the posterior end of the uro-cardiac ossicle and the power is applied by the exo-pyloric ossicles at its posterior border while work is done at a point near the fulcrum in pressing down the uro-cardiac tooth

On the supposition that the operation of the gastric armature is effected by the contraction of the anterior gastric muscles, Pearson (1908) locates both the point of application of power and fulcrum at the place of articulation of the zygo-cardiac ossicle with the outer end of the ptero-cardiac

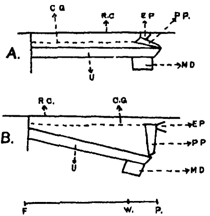

Fig 13

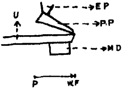

Fig 14

ossicle while the work is turned out at the zygo-cardiac tooth and describes the action of the zygo-cardiac tooth as that of the lever of the second order, considering the zygo-cardiac and exo-pyloric ossicles as a single bar With the conditions described by him neither the zygo-cardiac ossicle with the exo-pyloric is a lever of the second order, nor is movement possible when power acts at the fulcrum But if the power were to act at the exo-pyloric ossicles—as it should by the contraction of the posterior gastric muscles—then the action of the combined ossicles is that of a lever of the second order with the fulcrum at the anterior end of the zygo-cardiac ossicle, the work being turned out in the region of the zygo-cardiac tooth and the power being applied at the exo-pyloric ossicles as shown in Fig 15

The pre-pectinal ossicles bearing the infra-lateral cardiac teeth do not seem to come into action during the play of the main ossicles Their action commences just after the cessation of the activity of the main ossicles When the armature is in its position of rest, the postero-inferior cardiac muscles which are attached to the posterior borders of the infra-lateral cardiac ossicles contract As the post-pectinal ossicles are fused with the infra-lateral cardiac ossicle, both at the posterior and anterior ends, the contraction of these muscles draw together the pectinal ossicles, so that the infra-lateral cardiac teeth meet in the middle line above the median tooth, brushing it as they come together These clean the furrows of the median tooth and thus serve to keep it clean for the next collision with the zygo-cardiac teeth The infra-lateral cardiac teeth are brought back to their original position by the contraction of the lateral cardiac systems of muscle which extend between the dorsal border of the zygo-cardiac ossicles and the anterior region of the infra-lateral cardiac ossicles. If we consider

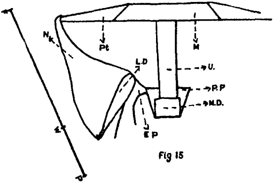

Fig 15

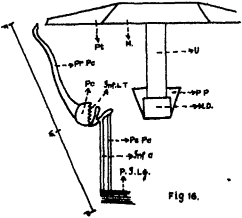

Fig 16.

the pectinal and infra-lateral cardiac ossicles as a single piece, their action is that of a lever of the second order The fulcrum is at the anterior extremity of the prepectinal ossicle at its articulation with the outer end of the ptero-cardiac ossicle and the work is turned out in the region of the infra-lateral cardiac teeth, while the power is applied by the postero-inferior cardiac muscles at the hind ends of the ossicle

Thus the entire operation of the gastric armature falls into two types, *viz*, (i) the action of the main system of ossicles and (ii) the action of the supporting system of ossicles The former is concerned with the crushing of the hard food materials while the latter is concerned with the cleaning of the crushed material from the furrows of the teeth borne by the main ossicles The two actions alternate The first is brought about by the extrinsic musculature while the second is effected by the intrinsic system

4. *Passage of the Food through the Digestive Tract*

The animals after a preliminary starving were fed on pieces of flesh stained with methylene blue and carmine The animals were killed at intervals of two to three hours each and the various regions of the alimentary canal were fixed in Bouin's fluid

Food is held by the chelæ and passed to the maxillipedes which after preliminary reduction transfer it to the chitinised mandibles After further reduction it is passed on into the mouth Through œsophagus it is passed into the cardiac fore-gut by the action of œsophagial musculature

No trace of the stains used with the food was detected in the mid-gut or the tubules of the digestive gland in the first four hours During this time the food is retained in the fore-gut and is subjected to the grinding action of the gastric armature and the straining processes of the gland filter. The digestive secretion from the digestive glands makes its way into the cardiac chamber along the ventral grooves (*V D* Fig 2) of the gland-filter and mixes with the fine particles of food material as shown by Yonge (1924) The fluid with the digested food in very fine particles then passes back through the gland-filter into the mid-gut All large particles are retained in the cardiac fore-gut till they are reduced to a fine state After ten hours methylene blue and carmine can be detected in the mid gut, mid-gut cæca and the tubules of the digestive gland. The absorption of the digested matter takes place within the mid-gut and its connected structures. The undigested matter is forced into the hind-gut by the peristaltic movements of the mid-gut. These peristaltic movements are not very pronounced. It takes about 1·5 to 2 minutes for the completion of every peristaltic wave When the isolated mid-gut in a bath of saline medium was perfused with adrenaline and epinine in dilutions mentioned before, the peristaltic movement was remarkably accelerated It took about a minute for the action of the adrenaline to start 7 to 8 peristaltic waves per minute were produced

In about 12 to 16 hours, the undigested matter enters the hind-gut and is finally expelled through the anus The stains used with the feeding of the animals are detected in all regions of the hind-gut during this time

The peristaltic movements of the hind-gut are more pronounced than those of the mid-gut Four to six peristaltic waves per minute are noticed Every peristaltic wave starts from the anterior end of the hind-gut, quite independent of the peristaltic waves of the mid-gut and passes towards the anus which is extended with every wave

Perfusion of the isolated hind-gut with adrenaline and epinine in dilutions mentioned above accelerates the peristaltic rhythm

Sometimes a few unreduced hard pieces escape the cardio-pyloric valve and are found in the spacious anterior third of the pyloric chamber The concrescence of the supra-ampullary ridges effects a complete separation of the dorsal and the ventral regions of the posterior two-thirds of the pyloric chamber Due to the resistance offered by the profuse setæ of the gland filter in the ventral division, the unreduced pieces which have escaped the cardio-pyloric valve are forced into the dorsal division whereas the digestive secretion with dissolved food and very fine particles alone pass through the gland-filter of the ventral division Mention has already been made about five to six flap-like processes projecting backwards from the posterior end of the pyloric chamber into the mid-gut Huxley (1880) and Mocquard (1883) suggest that these act as valves in preventing regurgitation of the contents of the mid-gut into the fore-gut Pearson (1908) and Cuenot (1893) state that these are concerned in carrying the hard pieces from the dorsal division directly into the hind-gut, thus preventing the soft walls of the mid-gut from damage Yonge (1924) agrees with Huxley (1880) and Mocquard (1883) In *Nephrops* which has a long mid-gut such a direct carriage of particles from fore-gut to hind-gut by the flap-like processes is not possible. But in *Paratelphusa* the mid-gut is very short and the valves in all probability are concerned in carrying these hard pieces directly from the fore- to the hind-gut

5 *Specificity of Digestive Enzymes*

The digestive secretion produced by the secretory or ferment cells of the digestive gland is a thick yellowish brown fluid This makes its way into the cardiac chamber through the grooves in the gland-filter and is mixed up with the food. The secretion is easily obtained by pushing a glass tube into the cardiac fore-gut through the mouth and drawing off the fluid therein. For experimental purposes glycerine extracts of the digestive glands were prepared. Only extracts of 20% strength were used in the reactions. Boiled extracts were set up as controls. Toluene was used as an antiseptic and the digests were incubated at 35° C.

The digestive secretion is poured into the lumen of the tubules of the gland in the form of fine yellowish droplets. Sections of the gland reveal some of the secretory cells actually emptying their contents into the lumen of the tubule. The secretion is faintly acidic towards litmus. As *Nephrops* (Yonge, 1924) it shows no trace of free acids. The secretion contains amylolytic, proteolytic and lipolytic enzymes.

The main results of the experiments connected with the amylolytic enzyme are shown in Table I. Starch, glycogen, sucrose are digested. It has no action on inulin and raffinose as in the case of *Nephrops* (Yonge,

TABLE I

No	Experiment	Time	Result
1	(A) 15 c c of 20 % extract + 15 c c of 1% Starch medium, neutral	5 hours	Titrated into 10 c c of Benedict's solution (A) 17 5 c c
	(B) ,, medium 2 N HCl	,,	(B) 35 0 c c
	(C) ,, medium 2 N Na_2CO_3	,,	(C) 42 0 c c
2	(A) 15 c c of 20% extract + 15 c c of 5% glycogen	3 hours	Titrated into 5 c c of Benedict's solution (A) 5 5 c c
	(B) ,, Boiled	,,	(B) 17 0 c c
3	(A) 15 c c of 20% extract + 15 c c of sucrose	,,	(A) 5 0 c c
	(B) ,, Boiled	,,	(B) 17 5 c c
4	(A) 15 c c, of 20% extract + 15 c c of 1% inulin	,,	(A) 14·0 c c
	(B) ,, Boiled	,,	(B) 14 0 c c
5	(A) 15 c c of 20% extract + 15 c c of 1% raffinose	,,	(A) 16 0 c c
	(B) ,, Boiled	,,	(B) 16 0 c c
6	(A) 20 c c of 20% extract + 1 gm saw dust	8 days	(A) 7 4 c c
	(B) ,, Boiled	,,	(B) 36 9 c c

1924) But traces of cytase as in *Astacus* (Bidermann and Moritz, 1898) are revealed by the action of the enzyme on saw-dust which contains hemicelluloses

The optimum temperature for the action of the enzyme was then determined. The results of the experiments are shown in Table II and are represented graphically in Fig 17 The optimum lies at 45° C. Similarly,

TABLE II

No	Experiment	Temperature	Result
A	10 c c of 20% extract + 10 c c of 2% starch solution was incubated for 6 hours at	30° C	At the and of 6 hours each digest was boiled, filtered, made up to 20 c c and titrated into 15 c c of Benedict's solution 10 2 c c
B	do	38° C	10 1 c c
C	do	40° C	10·0 c c
D	do	42° C	9 9 c c
E	do	44° C	9 8 c c
F	do	46° C	9 8 c c
G	do	48° C	10 0 c.c.
H	do	50° C	10 2 c.c.
I	do	52° C	10 3 c c

TABLE III

No	Experiment	Temperature	Result
A	10 c c. of 20% extract was kept for 30 minutes at	54° C	10 c c of 2% starch was added and incubated at 36° C for 3 days Then boiled, filtered, made up to the same volume and titrated into 15 c c of Benedict's solution 10 4 c c
B	do.	56° C	10 4 c.c
C	do	58° C	10 8 c c
D	do	60° C	11·4 c.c
E	do.	62° C	12 3 c c
F	do.	64° C.	26 0 c c.
G	do.	66° C.	26·0 c c
H	do.	68° C.	26·0 c.c.

the temperature of destruction was also determined The results are shown in Table III The temperature of destruction lies at 62° C It is interesting to compare these results with those obtained by Yonge (1924) in the case of *Nephrops* *Paratelphusa* lives under warmer conditions than *Nephrops* and still the optimum temperature and temperature of destruction of the amylolytic enzyme are lower than those of *Nephrops* (Yonge, 1924).

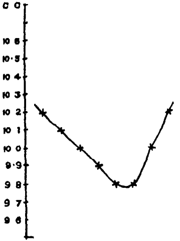

Fig 17

The proteolytic enzyme present is most active in alkaline medium and is almost inhibited in acid medium Fibrin, casein and peptone are digested The optimum degree of alkalinity for the action of the enzyme was then determined The method of Yonge (1924) was adopted Digests with various degrees of alkalinity were set up with ·5 g of fibrin in each They were incubated at 36° C for 3 days and then boiled, filtered and made up to the same volume. 20 c c of 10% formaldehyde was added to each and titrated into N/10 Na_2CO_3 with phenolphthalein as indicator The following results were obtained :

Neutral .	5·4 c c
N/80 Na_2CO_3 ..	6·8 c c
N/40 ,, .	7·1 c c.
N/30 ,, ..	7·2 c c
N/20 ,, ..	8·9 c c.
N/10 ,, ..	8·9 c c.

The optimum alkalinity as in the case of *Carcinus* (Roaf, 1908) and *Nephrops* (Yonge, 1924) is in N/20 Na_2CO_3 medium

The lipolytic enzyme shows a wide range of action. It hydrolyses methyl acetate, amyl acetate, butyl acetate, ethyl acetate and an emulsion of olive oil

The digestive secretion also hydrolises amygdalin and salicin Phloridzin was not acted upon

The digestive gland in addition to the functions of digestion and absorption according to Cuenot (1893) has also excretion, elimination and regulation Carmine and methylene blue which were injected into the abdomen were detected in the tubules of the digestive gland This phenomenon as Yonge (1924) has already pointed out, is of little importance in the excretory process

6 *Nature of Absorption and Food Reserves*

For investigating the absorption within the gut the animals were first starved for three days and then some were fed on olive oil stained with Sudan III while others were fed on ferrous oxydatum saccharatum Those fed on olive oil were used for detecting absorption within mid-gut and mid-gut cæca These were fixed in Fleming's solution without acetic acid In the case of the tubules of the digestive gland where there is a lot of stored fat the olive oil process is of no use Experiments on starving and subsequent sectioning of the gut have revealed that fat can persist in the cells of the digestive gland up to 38 to 40 days The absorption cells at this stage are clear and in many cases distorted For detecting absorption in the tubules of the digestive gland animals fed on iron salts were fixed in ammonium sulphide in 95% alcohol

The absorptive cells of the mid-gut and mid-gut cæca showed the presence of dark-staining fat droplets No trace of absorption was noticed in the fore-gut, hind-gut and hind-gut cæcum The ferment or secretory cells of the mid-gut are free from these darkly staining globules

In sections of the digestive gland iron salts are found profusely in the lumen of the tubules and in the vacuoles in the absorptive cells of the tubules The presence of iron salts in the absorptive cells of the mid-gut and mid-gut cæca is easily noticed

Cuenot (1893) and Jordan (1904) considered that the mid-gut and the mid-gut cæca are specialised for fat absorption There is however no reason for that assumption Animals were starved up to 40 days till almost all the fat in the absorptive cells disappeared They were then fed on olive oil and after 4 days fixed in Fleming's solution without acetic acid Section of both the digestive gland as well as those of the mid-gut and mid-gut cæca revealed the presence of darkly staining globules This clearly show that absorptive cells of digestive gland tubules also are capable of absorbing fat. These, however, were in greater profusion in the mid-gut and mid-gut cæca This is evidently due to the fact—as Yonge (1924) has pointed out—that carbohydrates and proteins which are easily split up make their way immediately into the tubules of the digestive gland, from the fore-gut, whereas fats which are more slowly split up are passed on into the mid-gut

Though the mid-gut is very small the absorptive surface is very much increased by the lumen of the two long mid-gut cæca and the tubules of the digestive gland

Within the absorptive cells of the digestive gland fats, glycogen and calcium salts are found as reserves Bernard (1853), Smith (1914), Kirch (quoted by Yonge, 1924), Paul and Sharpe (1919) have shown the close connection of these food reserves with the moulting in the case of many other Decapods.

7 *Summary and Conclusion*

1. *Paratelphusa* (*Oziotelphusa*) *hydrodromus* (Herbst) is the common South Indian field crab It is a fresh-water animal which lives in deep peculiarly oblique burrows.

2 The alimentary canal falls into three natural divisions, *viz*, (i) fore-gut, (ii) mid-gut and (iii) hind-gut The fore-gut consists of the œsophagus, cardiac chamber and the pyloric chamber The mid-gut is the shortest portion of the gut Immediately behind the fore-gut it is produced into two cæca The digestive gland opens into the mid-gut at this region by two lateral ducts The hind-gut is the longest portion Anteriorly arising from the right side is a cæcum. The histological structure of the various regions is described

3 The gastric armature present in the fore-gut is worked by a number of muscles. Its mechanical constitution is such that the force of a single pull is resolved along three teeth-bearing ossicles which collide The force of collision is so great as to reduce even the hard shells of molluscs to a fine powder

4 The *modus operandus* of the gastric armature is brought about by the posterior gastric muscles The cardio-pyloric constrictors and the anterior gastric muscles are concerned in the restoration of the gastric armature to its position of rest The various views regarding the working of the different ossicles are discussed.

5 After external reduction by the mandibles food is passed into the fore-gut where it is retained for four hours Here it is subjected to the elaborate processes of mastication and straining by the gastric armature and glandfilter The digestive secretion from the digestive glands finds its way into the cardiac chamber and mixes with the reduced food In about ten hours the food mixed up with the secretion passes into the mid-gut and its connected structures In 12–16 hours it reaches the hind-gut and is finally expelled through the anus Peristaltic movements of the mid- and hind-guts are responsible for the passage of food in the gut

6 The mid-gut exhibits feeble peristalsis, each peristaltic wave taking 1 5 to 2 minutes for its completion The hind-gut shows pronounced peristalsis—4 to 6 waves occur per minute When perfused with adrenaline and epinine in dilutions of 1/80,000 and 1/1,00,000 respectively, the peristaltic rhythm in both the cases was very much accelerated

7. Amylolytic, proteolytic and lipolytic enzymes are present in the digestive secretion Amylolytic enzyme acts best in neutral medium and digests starch, glycogen, sucrose. Its optimum temperature is 45° C and temperature of destruction is 62° C Hemicelluloses in saw-dust were also acted upon showing the presence of a cytase. Proteolytic enzyme has an optimum in N/20 Na_2CO_3 medium Lipolytic enzyme has a very wide range of action It hydrolyses fats and esters.

8 Absorption is confined to the mid-gut, mid-gut cæca and tubules of the digestive gland It is observed that fat is absorbed both in the mid-gut and the digestive tubules There is no evidence to show the assumption of Cuenot (1893) and Jordan (1904) regarding the specialisation of the mid-gut for fat absorption.

9 Fats, glycogen and calcium salts are found as reserves in the cells of the digestive glands

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EXPLANATION OF FIGURES

Fig 1—Alimentary Canal of *Paratelphusa*

Fig 2—T S of the posterior third of the pyloric chamber × 43

Fig 3—T S of the mid-gut × 72

Fig 4—T S of the mid-gut × 58

Fig 5—T S of the tegumental glands × 232

Fig 6—T S of the digestive tubule × 174

Fig 7—A secretory cell just before discharging its secretion × 580

Fig 8.—An absorption cell with vacuoles of absorbed food material. × 580

Fig. 9—A secretory cell discharging its secretion. × 580.

FIG 10—A secretory cell showing the formation of the vesicle of secretion × 580

FIG 11—The longitudinal chitinous ridges bearing setæ in the ampullary pouches × 43

FIG 12—The gastric armature with the main ossicles separated The pectinal system of ossicles of the left side alone is shown

FIG 13—Diagram to illustrate the mode of action of the uro-cardiac ossicle
A Position at rest
B Position at action

FIG 14—Diagram to show the action of pro-pyloric ossicle

FIG 15—Diagram to show the action of zygo-cardiac ossicle

FIG 16—Diagram to show the action of the pectinal system of ossicles

FIG 17—Temperature curve of the amylolytic enzyme

REFERENCE LETTERS

A C	Absorption Cells
B C.	Basal Cells
B S.	Blood Sinus
C.	Cardiac Chamber
C G.	Cardio-pyloric Constrictors
Ch.	Chitinous layer
C M.	Circular Muscles
C T	Connective Tissue
D D	Dorsal division of the pyloric chamber
Dg	Digestive gland
E.	Epithelium
E P	Exo-pyloric ossicle
F.	Fulcrum
H C	Hind-gut Cæcum
Hg.	Hind-gut
I.Amp	Inter-ampullary ridge
I C	Infra-lateral cardiac ossicle
Int D	Intra-cellular duct
Inf L.T.	Infra-lateral cardiac teeth
K'	Inner Knob-like process of the zygo-cardiac ossicle
K''	Outer knob-like process of the zygo-cardiac ossicle
L C	Lateral cardiac Plate
L D	Lateral or zygo-cardiac tooth
L M	Longitudinal muscles
L.C P.	Lateral cardio-pyloric ossicle
L M I	Inner longitudinal muscles
L.M.O.	Outer longitudinal muscles
M.	Meso-cardiac ossicle
M C	Mid-gut Cæcum
M D	Median or uro cardiac tooth
Mg	Mid-gut
N	Nucleus
P.	Power
Pc	Pectinal ossicle
P P	Pro-pyloric ossicle
Pt.	Ptero-cardiac ossicle
P V	Cardio pyloric valve
Py	Pyloric Chamber
P I Lg	Posterior infra lateral cardiac muscles
Pr Pc	Pre-pectinal ossicle
Ps Pc	Post-pectinal ossicle
R C.	Roof of the Cardiac Chamber
R S	Longitudinal setose ridges in the ampullary pouches
S	Secretion
S B	Striated border
S C	Secretory cells
Se	Setæ
S Amp	Supra-ampullary ridge
U.	Uro cardiac ossicle
V D	Right half of the ventral division of the pyloric chamber
V F	Vacuoles with absorbed food material
V s	Small vesicles of secretion in formation
V S	Vesicle of secretion
W.	Work
Z.	Zygo-cardiac ossicle

FUNGI OF ALLAHABAD, INDIA.—PART III.

BY J. H. MITTER AND R N TANDON

(From the Department of Botany, Allahabad University, Allahabad)

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[Communicated by Dr Shri Ranjan, M.Sc (Cantab.), Docteur ès Sciences.]

SINCE the publication of Part II of "The fungus flora of Allahabad" a number of other fungi have been collected in this town which are included in this third list

Special interest attaches to this list of fungi on account of the following points :—

(1) Allahabad is not specifically mentioned by Butler and Bisby in "The fungi of India" as a locality for any of these fungi

(2) Some of the species are on new hosts They are marked with an asterisk

(3) Some of these fungi are not recorded in "The fungi of India" These are marked with a †

(4) Fifteen species and one genus in the list are described for the first time in *Annales Mycologici-Fungi indici*, Nos 1 and 2 by Sydow and Mitter and No 3 by Sydow, Mitter and Tandon These are marked with a double asterisk

Except a few, the fungi were collected by the authors.

No	Name of the fungus	Name of the host
	ARCHIMYCETES	
1	*Synchytrium rytzii* Syd	*Peristrophe bicalyculata*
	PHYCOMYCETES	
*2	*Choanephora cucurbitarum* (Berk & Rav) Thaxter	*Hibiscus esculentus*
3	*Choanephora infundibulifera* (Currey) Cunningham	*Hibiscus rosa-sinensis*

No.	Name of the fungus	Name of the host
	Choanephora ? simsoni Cunningham	*Zinnia* sp (cultivated)
	Cystopus bliti (Biv) de Bary	*Achyranthes aspera*
	Cystopus bliti (Biv) de Bary	*Amaranthus* sp
	Cystopus bliti (Biv) de Bary	*Digera arvensis*
*8	*Cystopus ipomœ-panduratæ* (Schw) Stevens & Swingle	*Ipomœa hirta*
*9	*Cystopus ipomœ-panduratæ* (Schw) Stevens & Swingle	*Ipomœa pestigridis*
*10	*Cystopus ipomœ-panduratæ* (Schw) Stevens & Swingle	*Ipomœa pilosa*
*11	*Cystopus ipomœ-panduratæ* (Schw) Stevens & Swingle	*Merremia emarginata*
12	*Peronospora arborescens* (Berk) de Bary	*Papaver somniferum*
†13	*Peronospora obovata* Bon	*Spergula arvense*
	Peronospora trifoliorum de Bary	*Medicago denticulata*
15	*Peronospora trifoliorum* de Bary	*Medicago indica*
*16	*Peronospora viciæ* (Berk) de Bary	*Vicia sativa*
17	*Phytophthora colocasiæ* Raciborski	*Colocasia antiquorum*
18	*Sclerospora graminicola* (Sacc) Schroeter	
	ASCOMYCETES	
**19	*Coronophora epistroma* Syd	*Phyllanthus reticulatus*
**20	*Diaporthe mitteriana* Syd	*Porana paniculata*
†21	*Hypoxylon nectrioides* Speg.	*Tamarindus indica*

No	Name of the fungus	Name of the host
22	*Hypoxylon rubiginosum* (Pers.) Fr	Dead wood
†23	*Pleospora bataanensis* Petr	*Agave americana*
24	*Protomyces macrosporus* Unger	*Coriandrum sativum*
✓ *25	*Triblidiella rufula* (Spreng.) Sacc.	*Albizzia odoratissima*
	BASIDIOMYCETES (a) *Ustilaginales*	
26	*Melanopsichium austro-americanum* (Speg.) Berk	*Polygonum glabrum*
27	*Ustilago eleusinis* Kulkarni	*Eleusine ægyptiaca*
28	*Ustilago Kolleri*	*Avena sativa*
	(b) *Uredinales*	
29	*Puccinia kuehnii* (Krueg.) Butler	*Saccharum* sp
30	*Puccinia penniseti* Zimm	*Pennisetum typhoideum*
**31	*Uromyces gentilis* Syd	*Mimusops hexandra*
32	*Uromyces setariæ-italicæ* (Diet.) Yoshino	*Setaria italica*
✓ 33	*Uromyces* sp	*Saccharum arundinaceum* (No *Uromyces* is mentioned on this host)
	(c) *Hymenomycetes*	
34	*Amanita* sp	
35	*Boletus* sp	
36	*Dædalea flavida* Lév	
37	*Dædalea unicolor* (Bull.) Fr	

No	Name of the fungus	Name of the host
38	*Favolus scaber* B and Br	
†39	*Fomes caryophylli* (Rac) Bres	
40	*Fomes durissimus* Lloyd	
41	*Fomes pallidus* Petch	
42	*Fomes rimosus* Berk	
†43	*Fomes robustus* Karst	
44	*Fomes senex* Nees & Mont	
45	*Ganoderma colossum* (Fr) Bres	
*46	*Hexagonia discopoda* Pat & Har	*Bassia latifolia*
*47	*Hexagonia discopoda* Pat & Har	*Tamarindus indica*
48	*Irpex* sp	
49	*Lentinus* sp	
50	*Lenzites repanda* (Mont) Fr	
51	*Polyporus calcuttensis* Bose	
52	*Polyporus chocolatus* Bose	
53	*Polyporus gramocephalus* Berk	
54	*Polyporus hookeri* Lloyd	
†55	*Polyporus nilgheriensis* Mont	
56	*Polystictus hirsutus* Fr	
57	*Polystictus leoninus* Klotzsch	
58	*Polystictus velutinus* Fr.	

No	Name of the fungus	Name of the host
†59	*Poria lacrigata* Fr	
60	*Poria* sp.	Bamboo
*61	*Poria* sp	Palm
*62	*Poria* sp	*Vites negundo*
*63	*Poria* sp	*Zizyphus jujuba*
64	*Trametes cingulata* Ber	
65	*Trametes floccosa* Bres	
66	*Trametes persooni* Fr	

(*d*) *Gasteromycetes*

67	*Cyathus* sp	
68	*Podaxon* sp.	

FUNGI IMPERFECTI

69	*Acrothecium lunatum* Wakker	*Andropogon sorghum*
70	*Alternaria solani* (Ell and Mart.) Jone & Grout	*Solanum tuberosum*
†71	*Ascochyta cycadina Scalia*	*Cycas revoluta*
†72	*Botryodiplodia dracænicola* (P Henn) Petr *et* Syd	*Dracæna* sp
†73	*Botryodiplodia mamlensis* (Sacc) Petr *et* Syd	*Ricinus communis*
†74	*Botryodiplodia syconophila* (Sacc) Petr *et* Syd	*Ficus religiosa*
75	*Cephalosporium* sp	*Helianthus* sp.

No.	Name of the fungus	Name of the host
**76	*Cercoseptoria balsaminæ* Syd.	*Impatiens balsam*
77	*Cercospora beticola* Sacc	*Beta vulgaris*
78	*Cercospora cruenta* Sacc	*Vigna catiang*
**79	*Cercospora indica*	*Cajanus indicus*
✓ †80	*Cercospora moricola*	*Morus alba*
**81	*Cercospora myxa* Syd	*Cordia myxa*
82	*Cercospora occidentalis* Cke	*Cassia occidentalis*
83	*Cercospora personata* (Berk and Curt) Ell & Ev	*Arachis hypogæa*
**84	*Cercospora pulchra* Syd	*Cratæva religiosa*
**85	*Cercospora sissoo* Syd	*Dalbergia sissoo*
✓ †86	*Cercospora tinospora* Syd	*Tinospora cordifolia*
*87	*Cercospora* sp	*Coccinia indica*
*88	*Cercospora* sp	*Melilotus alba*
**89	*Cercosporella peristrophes* Syd	*Peristrophe bicalyculata*
**90	*Ciliochorella mangiferæ* Syd Nov Gen. Nov Sp.	*Mangifera indica*
91	*Cladosporium fulvum* Cke	*Lycopersicum esculentum*
**92	*Clasterosporium concinnum* Syd	*Ficus religiosa*
†93	*Colletotrichum dracænæ-fragrantis* (Movi) Petr *et* Syd	*Dracæna ? lindii*
†94	*Colletotrichum papayæ* (P Henn) Syd.	*Carica papaya*

No	Name of the Fungus	Name of the Host
**95	*Colletotrichum tinosporæ* Syd	*Tinospora cordifolia*
**96	*Dendrographium mitteri* Syd	*Tinospora cordifolia*
*97	*Diplodia hibiscina* Cke *et* Ell -Var *Sabdariffæ sacc*	*Hibiscus sabdariffa*
98	*Diplodia* sp	*Porana paniculata*
99	*Dothiorella* sp	*Porana paniculata*
†100	*Exotrichum leucomelas* Syd	*Peristrophe bicalyculata*
101	*Haplosporella dracænarum* (Penz *et* sacc) Petr	*Dracæna* sp
**102	*Haplosporella phyllanthina* Syd	*Phyllanthus reticulatus*
†103	*Isaria pulcherrima* Berk *et* Br	*Phœnix dactylifera*
**104	*Lamyella planiuscula* Syd	*Mimusops elengi*
†105	*Macrophoma dianthi* Gobotto	*Dianthus caryophyllus*
106	*Microdiplodia agaves* (Niessl) Petr	*Agave americana*
107	*Microdiplodia agaves* (Niessl) Petr	*Agave cantala*
**108	*Phomopsis artocarpi* Syd	*Artocarpus integrifolia*
†109	*Phyllosticta ? confertissima* Ell *et* Ev	*Ulmus integrifolia*
†110	*Phyllosticta dracænæ* Griff *et* Maubl	*Dracæna ? lindii*
111	*Phyllosticta violæ* Desm	*Viola* sp.
*112	*Phyllosticta* sp.	*Antigonum* sp
113	*Phyllosticta* sp	*Phœnix* sp.
114	*Septoglœum acaciæ* Syd	*Acacia arabica*

No.	Name of the Fungus	Name of the Host
✓†115	*Septoria calystegiæ* West	*Convolvulus arvense*
†116	*Trichothecium roseum* Lk	Old wood
✓†117	*Vermicularia backleri* Syd	*Ricinus communis*

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IS THE CHROMOPHOBIC PART OF THE GOLGI APPARATUS AND MITOCHONDRIA THE ERGASTOPLASM?

By M K Subramaniam, M A , D Sc ,

Research Fellow, Department of Zoology, University of Madras

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(Communicated by Professor R Gopala Aiyar)

Introduction

Very recently from work on *Lycastis* (Subramaniam and Gopala Aiyar, 1936, 1937) it was postulated that in the vertebrates the idiosome should be present in a masked condition as a core to the strands or plates composing the Golgi network. Since then, the problem is being studied from two directions. First, I proceeded on the assumption that if such a core is present in a masked condition, it should be seen during the active synthesis of secretion granules at least in some cases During experiments with various types of vertebrate tissues it was found that in the liver cells of the tree frog, actually, a chromophobic part becomes differentiated during secretion of bile components (Subramaniam, 1937) In the second line of attack, the pancreas of the toad was selected, where, the chromophobic part of the Golgi apparatus is not visible at any stage If as has been postulated (Subramaniam and Gopala Aiyar, 1936 and 1937) a chromophobic part is present, it should be possible to demonstrate it by some suitable technique Bowen (1928) describing certain methods employed by some workers for the demonstration of the idiosome in germ cells suggests their application to vertebrate somatic cells The fixatives suggested are Bouin, Perenyi, Zenker, Mann or Osmic Acid The stains used are erythrosin, light green, acid fuchsin, methyl green and resorcin-fuchsin It will be seen that most of the fixatives mentioned above contain acetic acid or mercuric chloride and most of the dyes are acid ones The special technique for cytoplasmic components is being followed rigidly only in recent years and the earlier workers employed mostly acetic acid or sublimate fixatives From a study of the earlier papers on the pancreas it appears that it is from acetic acid and mercuric chloride preparations of gland cells that the Ergastoplasm theory was formulated Though not heard of now, the Ergastoplasm theory held sway between the years 1890 and 1910

What is the Ergastoplasm Theory?

Nebenkern.—In order to get a clear idea of the Ergastoplasm theory, it is desirable to know something about the 'Nebenkern' described in some gland cells. This structure described particularly in the pancreas has nothing to do with structures of similar name described in pulmonate germ cells and insect spermatids. Gaule (1881) and Nussbaum (1882) discovered independently in the pancreas cell a body of uncertain nature which they called the 'Nebenkern'. This structure in a gland cell is a mass often of fibrillar structure, the nature and function of which is still in dispute. According to the description of Nussbaum the development of the 'Nebenkern' is related to the phase of the secretory cycle. Thus cells actively synthesizing secretory products were found to have one or more large 'Nebenkerns', while in cells loaded with secretion the 'Nebenkern' might be absent. Ogata (1883) found during his researches on the frog and other Amphibia, that the 'Nebenkern' was most common in frogs which had not been fed for a short time. It disappeared later and appeared again only after feeding. Curious and fantastic descriptions of the origin and structure of the 'Nebenkern' are seen in literature. Morelle (1927) considered that faulty fixation produced a 'Nebenkern' while Benoit (1926) assigns to it a minor place in cellular economy.

Ergastoplasm.—Side by side with the Nebenkern conception was developed the Ergastoplasm theory. Briefly, the so-called Ergastoplasm is constituted by filaments and these are usually seen only after acetic acid or corrosive sublimate fixations. It should be pointed out here that some workers considered that these filaments seen in sublimate and acetic acid fixations, formed the so-called 'Nebenkerns' of the pancreas, due to spiral twisting or coiling (Mathews, 1899). A clear account of these fibrillar structures was first given by Eberth and Muller (1892). Solger (1894, 1896 and 1898) described them in detail under the name 'basal filaments' and as 'Ergastoplasm' their importance was emphasized by Garnier (1897, 1900 *a*, 1900 *b*) and Prenant (1898–99).

The morphology of this structure was never clearly defined but as the name 'Solger's filaments' suggests, it had frequently a fibrillar structure. Divergent structures have been included under the term 'Ergastoplasm' due to their supposed common affinity for acid stains, like chromatin, but if one has to believe Mathews (1899) both have slightly different staining reactions as the following statement of his would show: "In Pl. XI, Fig. 31*c* one of these threads, stained red runs over the nucleus and ends in the green mass of chromatin" (p. 178). This is in the pancreas cell of the hen, fixed in Hermann and probably stained in acid fuchsin and methyl green. The most interesting aspect of the Ergastoplasm theory seems to be the conception of its alteration in amount (and staining capacity) at different parts of the secretory cycle. Garnier (1900 *a*, 1900 *b*), Prenant (1898-99), Jacobs (1928) and many others have shown that in cells actively synthesizing secretory droplets the Ergastoplasm is fully developed while in cells loaded with secretion it is greatly reduced or entirely absent. Though most of the workers were against the idea of the Ergastoplasmic fibrillæ being actually transformed into secretory granules, yet, the majority agreed with the view that the development of the Ergastoplasm is precedent to the secretory substance proper.

Coming actually to the disposition of the filaments or fibrillæ, they have been known to run chiefly in a vertical direction beside the nucleus, while below the nucleus they run in a horizontal direction forming an intricate skein (Bensley, 1911). The Ergastoplasm has been interpreted as artifacts produced by acid fixation by some, while others opine that the Ergastoplasm has a material existence in the form of an unformed material which becomes fibrillar when treated with fixatives which are too acid.

Bowen (1929) sums up with the observation that two different things have been confused under the name Ergastoplasm (1) the poorly fixed chondriome and (2) the concentrated material in the basal region of the cell coming from the capillaries.

The Ergastoplasm and the Chromophobic Part of the Golgi Apparatus and Mitochondria

My interest in the Ergastoplasm and Nebenkern concepts has been due to the fact that technique once used for the demonstration of the Ergastoplasm and Nebenkern has been found successful for the demonstration of the idiosome in germ-cells. If structures shown by such technique could be considered the idiosome, cannot similar structures shown by similar technique in gland cells also be partly or wholly due to the idiosomic substance? In order to discuss the above question one has to have a definite idea of the structure of the mitochondria and the Golgi apparatus. The mitochondria are filamentous in the pancreas and no chromophobic component has been demonstrated in relation with the outside of these filaments by any worker. Bowen (1922) from his researches on the Nebenkern formation during spermatogenesis in insects comes to the conclusion that these filamentous mitochondria should have a chromophobic area in the centre which though not visible is supposed to be present. In other words, the chromophobic core is supposed to occupy a position similar to that of the copper wire in an insulated cable (Fig 1) Similarly, Subramaniam and Gopala Aiyar have suggested that a central chromophobic core should be present in Golgi networks which do not show any visible chromophobic

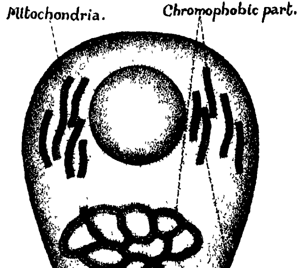

Fig 1

area Both the possibilities have been substantiated in part by demonstration of the differentiation of a chromophobic part in mitochondria during Nebenkern formation and the differentiation of a chromophobic area by the strands of the Golgi network in the liver cells of the tree frog during production of bile constituents The chromophobic part of the mitochondria and Golgi apparatus are supposed to be of a proteid composition It is rather unfortunate that while the chromophobic part of the Golgi apparatus has a definite name—the idiosome—there is no such term for the chromophobic part of the mitochondria That the idiosome at least is of a proteid nature could be made from the tests suggested by Bowen (1928) for the demonstration of such a component and with which many workers record a demonstration of the idiosome

The question that has to be considered is, can the Ergastoplasm be the chromophobic parts of the Golgi and Mitochondria? Bowen (1929) suggests that part of the Ergastoplasm may be only a remnant of the poorly fixed chondriome The question arises, which part or component of the chondriome is the part that persists? It is common knowledge—though a controversy has been raging on the subject—that many workers consider the mitochondria as having a proteid-lipoid composition Bowen's suggestion cited above should prove that it is the proteid part that persists, for, lipoids and fats are washed out by corrosive acetic and acetic acid fixatives A similar proteid-lipoid composition has been attributed to the Golgi apparatus also, but the proportion of the substances are said to be different from that in mitochondria It is common knowledge that the chromophobic part of the Golgi apparatus in male germ cells has been long known to cytologists under various names, even before the fact that it only forms a part of the Golgi apparatus Recently, Poisson (1927) has demonstrated this component of the Golgi apparatus by a technique originally devised for connective tissue and the detection of mucin Mucin, it will be interesting to note, is of a proteid nature and hence necessarily the idiosome should also have a proteid composition Thus we find that the methods employed by the supporters of the Ergastoplasm theory and those who have demonstrated the idiosome were identical The reason why it escaped the attention of Bowen (1929) who gave a brilliant review of the Ergastoplasm theory as also the methods for the demonstration of the Golgi apparatus and the idiosome (1928) is due to the fact that he paid little attention to the structure of the Golgi apparatus and the mitochondria

Now it remains to consider the reasons for and against a consideration of the Ergastoplasm as the chromophobic part of the Golgi apparatus and the mitochondria From a perusal of the literature it appears to me that one of the serious objections is that the filaments of Solger occur only in gland cells, for example in the acinar cells of the pancreas, while the mitochondria occur in acinous cells as well as epithelial cells It should be pointed out here that great changes in volume and distribution of the Golgi apparatus and the mitochondria occur only in actively secreting cells and not in epithelial cells and a perusal of the papers and Text-books on Histology will show that the shape and complexity of the Golgi apparatus and mitochondria vary in sections of a particular organ composed of different types of cells * Thus the objection cited above is of little value A more important consideration raised by Bensley (1911) seems to be that the filaments of Solger were not seen in living material whereas the mitochondrial filaments were seen when stained with Janus green Bensley (1911) seems inclined to believe that the basophile filaments are fixation artifacts due to acid precipitation He also suggests the other possibility that the Ergastoplasmic fibrillæ may be imbedded in a substance of the same refractive index, and that they may be rendered visible in acid fixations by contraction On this basis, according to him, it is necessary to assume that the filaments are swollen in chrome sublimate and formalin zenker preparations, so as to occupy apparently all the space in the cell not taken up by the mitochondrial filaments and fat globules Another argument of Bensley is that in pancreas fixed in acetic-osmic-bichromate, stained in anilin fuchsin and differentiated in methyl green the mitochondrial filaments are stained intensely red while the basal substance is green It will be seen that these objections are valid only if both have an independent existence When we conceive of the possibility of the Ergastoplasmic fibrillæ forming a core to the mitochondria it will be evident that the criterion of differential staining in the manner applied by Bensley does not convince one that the Ergastoplasmic fibrillæ are artifacts

Bensley makes a distinction between the filamentous mitochondria observed by him and the Ergastoplasmic fibrillæ by their obvious structure, namely, the mitochondria are coarse and bacillus-like, while the filaments of Solger are fine and often form an intricate skein If the possibility of the chromophobic part of the mitochondrial filaments forming the Ergastoplasmic fibrillæ is admitted, then they have necessarily to be fine filaments

Thus having considered some of the objections we shall pass on to the resemblances in topography between the Ergastoplasmic or Solger's filaments and the Golgi apparatus and the mitochondria Bowen (1926) and Hirschler (1918) are of opinion that the mitochondria and the Golgi apparatus have a lamellar structure This is exactly what has been postulated for the Ergastoplasm by innumerable authors who consider that the fibrillar appearance is only the sectional view of actual plate-like structures Bensley described mitochondria in the acinar cells of the pancreas as located for the most part in the basal portion of the cell Recent researches on the pancreas by Hirsch (1931 and 1932) and Duthie (1934) confirm the above observations of Bensley, but it appears to me that these authors have attached too much importance to this basal position of the mitochondria

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* See Ludford, *J.R.M.S.*, 1925, Fig. 3, p. 357; Cajal, *Histology*, 1934, Fig. 130, p. 167.

and attribute the production of prozymogen to the mitochondria. The Golgi apparatus is network-like and lies just below the nucleus I believe the fact that during secretory activity the Golgi apparatus and mitochondria increase in number and size needs no reiteration and elaboration Going further into the resemblances, I find that the earlier workers on Nebenkern and Ergastoplasm have emphasized the fact that in cells loaded with secretion the Ergastoplasmic fibrillæ and the Nebenkerns were absent Thus in almost all cases the development of the Nebenkern and Ergastoplasm has been viewed as in some sense precedent to the synthesis of the secretory material proper It is exactly at this stage, prior to and during synthesis of secretory materials that hypertrophy of the Golgi and mitochondria occur Thus having established the probability we shall consider the topography It should be pointed out here that under the term Nebenkern and Ergastoplasm all sorts of curious structures have been described The probability considered here is only that between the proteid structures usually showing basophilic reactions and the chromophobic part of the Golgi apparatus and mitochondria In most descriptions of the Ergastoplasmic fibrillæ they have been described to have a longitudinal disposition at the sides of the nucleus and a transverse disposition below the nucleus But even Bensley's descriptions seem to suggest that the images of Solger's filaments may not be superimposable on the pictures of the mitochondria and the Golgi apparatus obtained in the same cell Here, I believe the cause seems to be the principle of fixation Students of cytology will be familiar with the fact that the chromosome fixatives are quite unsuited for a demonstration of the mitochondria and the Golgi apparatus Moreover, solutions containing mercuric chloride and acetic acid do not fix fats and lipoids and hence during the various stages leading up to the clearing agent these have to escape from the tissue leading naturally to the production of currents in the cytoplasm which may be responsible for the production of incorrect pictures of Ergastoplasmic fibrillæ which do not fit in exactly with the pictures of mitochondria and the Golgi apparatus In this connection Mathews' (1899) observation seems to be interesting He teased living pancreas cells of *Necturus* in saline and while observing them under the microscope introduced mercuric chloride and other fixing agents When corrosive sublimate is thus introduced he saw these threads rendered visible at the first touch of the fixative, swinging rapidly back and forth in consequence, he suggests, of strong osmosis Apparently, what he saw was the mitochondria being shorn of its lipoidal part

Conclusion.

I am giving below diagrammatic representations of the position and supposed structure of the Golgi apparatus and the mitochondria (Fig 1) as also the Ergastoplasmic fibrillæ (Fig 2) in order to demonstrate the possibility of the chromophobic core of the Golgi and mitochondria being the Ergastoplasmic fibrillæ Though only further work on pancreas can justify this assumption, is it not possible that what are described under the terms Ergastoplasm and Nebenkern may, after all, be the chromophobic portions of the Golgi apparatus and the mitochondria?

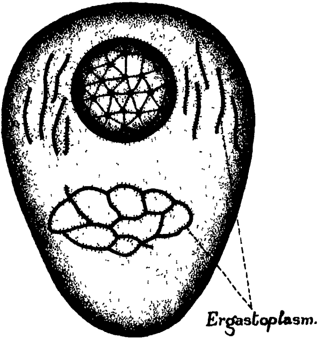

FIG. 2.

Acknowledgments.

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FURTHER NOTES ON THE HÆMOPARASITOLOGY OF THE INDIAN BIRDS.

By I. Froilano de Mello
AND
Luis da Fonseca
(*Medical College, Nova-Goa*)

Received September 30, 1937

In the present note we will give some statements concerning the Hæmoparasitology of the Indian Birds.

Trypanosoma gymnorhidis n. sp.
Parasite of Gymnorhis xanthocollis, Burton

This bird, shot at Santo Estevam, showed us in its blood smears besides the ***Hæmoproteus*** which has already been described and named *H. gymnorhidis*[1] some specimens of a Trypanosome, which will be named *Trypanosoma gymnorhidis* n. sp. as up to date no Trypanosome has been described in birds of the genus *Gymnorhis*.

The morphology of this flagellate agrees with the general form of such parasites. Its protoplasm is not uniformly stained by Romanowsky stain, as in some parts it shows some zones, irregularly scattered, taking a denser tinge.

The figure gives a perfect idea of the irregularity of form, number and situation of these zones.

Macronucleus central and surrounded by a large clear area. Very large, it occupies the whole breadth of the parasite, and has an ovoid form. In only one specimen (Fig. 3) its situation is rather subcentral, closer to the posterior pole. The macronucleus has a compact structure in fully grown-up individuals. It suffers a binary division whose initial process seems to begin by a kind of linear split in the middle of the endosomic mass (Figs. 2, 4).

The micronucleus is very small and sometimes not perfectly distinct (Fig. 2). It is situated at a certain distance of the pointed rostrum-like tail of the parasite.

The axoneme of the undulant membrane is generally in the form of a line deeply tinged with blue Even in slides stained by Heidenhain's iron-hæmatoxylin, in 50 per cent of the specimens, this organelle does not show a chromatic tinge In perfectly stained individuals, however, it can be seen, starting from the micronucleus through a fine thread which becomes larger at one to two microns of distance It continues bordering the undulant membrane and does not end in free flagellum

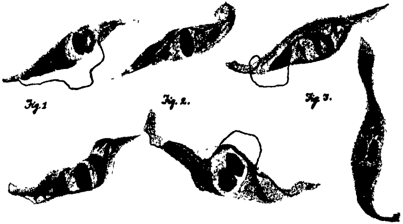


Fig. 1 Fig. 2. Fig. 3. Fig. 4. Fig. 5. Fig. 6.

Trypanosoma gymnorhidis

Measurements of Six Individuals (in Microns)

No. of specimens measured	1	2	3	4	5	6
From the posterior extr. to the kinetonucleus	6	2	1	1·5	5	5
From the kinetonucleus to trophonucleus	7	11	12	9	12	10
Breadth of the trophonucleus	2	2	2 5	2·5	3	2·5
Free flagellum	0	0	0	0	0	0

Hæmoproteid of Halcyon smyrnensis fusca (Bodd)

This bird, shot at Santo Estevam, identified by Dr Baini Prashad, has shown an intense parasitism by an *Hæmoproteid* with the following characters .—

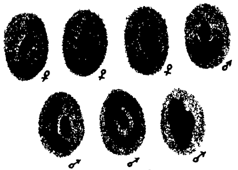
Sexual dimorphism, the male gametocytes being colourless or with a slightly blue tone not uniformly spread in the protoplasm when stained by Romanowsky The small forms are oval and when grown up they are haltheride-like, sometimes surrounding completely the nucleus of the red cell as both extremities of the parasite fuse together leaving often a certain amount of the red cell body unoccupied The pigment granules are of various sizes, often very minute, often large, isolated or assembled in clusters, showing, however, when compared with the female gametocyte, a tendency to be collected on the poles In small forms one or two granules only can be stated, but in large forms such granules are more abundant, specially in those very large, surrounding the nucleus of the red cell and in such cases they are scattered all over the body The nucleus of male gametocyte is very large, generally central, rarely sub-central and occupying a large part of the body, often without definite outline It is stained in rose by Leishmann's stain, reddish by May-Grunwald-Giemsa

With this last coloration the protoplasm of the parasite stains slightly reddish violet

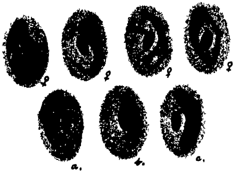
The female gametocyte, oval, fusiform or in the form of a slender haltherid, when young, is definitely haltheridic when grown up Often the haltherides are somewhat irregular As in the male gametocytes, both poles of the gametocyte fuse together and surround the nucleus of the red cell, when the parasite is fully grown up The protoplasm of the parasite is definitely blue with Romanowsky, but the stain is not uniformly spread The pigment is black-brown, or coffee-brown as in male gametocytes, but generally with a deeper tinge than in the male With May-Grunwald-Giemsa this pigment in female gametocytes takes sometimes a purple violet tone Its distribution as well as the size of the granules is irregular Some specimens show a polar location, but generally subcentral, rather with a polar location

The red cell is generally not altered when the parasite is young or medium sized The grown-up specimens displace the nucleus of the red cell to the periphery.

We have found some figures (note Figs *a* and *b*) which could not be correctly interpreted Besides the nucleus, they contained small rose corpuscles, which were not however of nuclear nature



Hæmoproteus I



Hæmoproteus II

In specimen *c*, we have a very nice type of *accolement* of two female haltherides, which could be mistaken for a nuclear division

The outline of both these parasites was clear enough for giving evidence of such accolement

Classification

Hæmoproteids have been described in

Halcyon lindsayi by Hegner and Chu, 1930 [2]

Halcyon senegalensis by Theiler, 1930 [3]

Halcyon smyrnensis (1935) by de Mello, the parasite having been named *Hæmoproteus halcyonis* [4]

Our parasite is not perfectly the same as *H halcyonis* from *Halcyon smyrnensis* We believe that it constitutes a mere variety which will be named *Hæmoproteus halcyonis fuscæ*

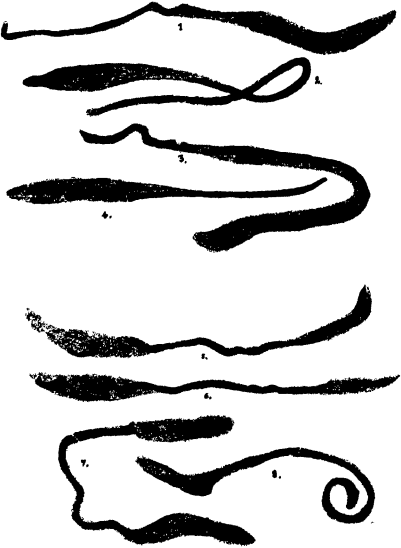
A New Microfilarium of Ardeola grayi Sikes (*shot at Santo Estevam*)

Provided with a conspicuous sheath this microfilarid shows its contents packed up in an uniform band-like structure without any distinct separation between them Its cephalic extremity often does not show any sheath appendix and the nuclear mass begins immediately behind the membrane, sometimes a small clear zone, where one or more granules are noticed, marks a rudiment of anterior sheath, which, in other specimens, is elongated as a glove finger and shows the same structure as the posterior appendix, generally fairly constant and much more developed The posterior extremity of the nuclear mass may be roundish, twisted or abruptly cut No definite spot is seen in the body only a split like interruption is found in the centre and rarely near the posterior end

The sheath appendices are very curious elongated as a glove finger and showing minute granules, scattered all over, fibrils irregularly twisted and patches of substances taking a violet stain with Romanowsky, whose location defies every description and is well figured in the illustrations

Measurements in Microns

No	Total length	Body length	Breadth	Breadth of sheath	Ant appendix of the sheath		Post appendix of the sheath	
					Length	Breadth	Length	Breadth
1	162	122	3·5	5	40	4	—	—
2	231·5	193	3·5	7	35	6	3	2·5
3	118	108	4	5·5	10	5·5	—	—
4	216	150	3·5	5	66	5	—	—
5	198·5	110·5	4	4·5	56	7	50	5
6	221	131	4	6	61	4·5	42	5
7	229	144·5	3	6	3·75	7	47	12
8	169	115	3·5	5	56	5	6	3



Microfilarium limai.

The senior author has described a microfilarium of this bird under the name ***Microfilarium ardeolæ***[4] The present microfilarium is a different species which we will name *Microfilarium limai* sp n as an homage to Prof J A Pires de Lima, from the Faculty of Medicine of Porto

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ON A CERCOMONAD PARASITE OF THE INTESTINAL TRACT OF THE PENTATOMID BUG *ASPONGOPUS OBSCURUS* (FABR.).

By I Froilano de Mello, Vanctexa Dessai
AND
Vamona Xeldencar.
(Medical College, Nova Gôa)

Received April 14, 1937.

Over fifty per cent of the specimens of the Pentatomid bug *Aspongopus obscurus* (Fabr), kindly identified by Dr Baini Prashad from the Zoological Survey of India, harbour in their intestinal tract a small cercomonad which will be described in this paper.

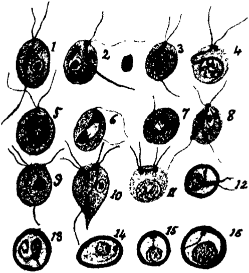
In living condition one cannot trace but the movements of the flagellate, whose structure, often very difficult to interpret on account of the small size of the parasite, is fairly well seen in material fixed by sublimate alcohol or Bouin and stained by Heidenhain's iron-hæmatoxylin.

The general morphology of the parasite is oval, rarely pyriform, the posterior pole having a pointed appearance (Fig 10) The membrane is of periplastic nature in active forms, the cytoplasm contains often some inclusions of, probably, nutritive material (Fig 2). The nucleus is oval, of protokaryon type, surrounded by a strongly siderophyl membrane and occupies a more or less central position (Figs 1, 2) On the anterior pole there is a rather large blepharoplast, which seems to us constituted by the fusion of at least two granules, whose union, in such case, takes the appearance of a rod (Fig 4) From this blepharoplast start three flagella: two very thin, having an equal size and directed forwards, one thicker, of cercomonadic type, adhering to the body which it crosses and becoming free on or near the posterior pole

The division occurs by mitosis and shows the following phases:—

(*a*) Premitotic stage where the nuclear karyosome becomes a sort of dust filling completely the endosome (Figs. 3, 9) giving, on a further stage, origin to spireme (Figs 11, 4).

(*b*) *Mitosis* where only the following stages could be observed: *prophase* with 4 chromosomes and *telophase* (Figs. 5, 6, 7, 8).



Trimitus ramaraoi n. sp.

The baso-flagellar apparatus suffers also a division, the daughter granules being attached by a desmose (Figs 8, 9, 10, 11)

The nucleus in mitosis is considerably enlarged and occupies various positions whose meaning remains for us obscure

We have not been fortunate enough to find figures with the division of the posterior cercomonadic flagellum.

The encystation of the flagellate occurs in the following way the membrane becomes much thicker than in active forms, the flagella suffer a kind of reabsorption, the remains of the cercomonadic flagellum being the last to disappear The nucleus seems to increase and the karyosome is reduced to chromatic dust It is quite possible that some process of division occurs also in the cystic stage, but we have no definite evidence on this point

Measurements—Five flagellates were measured and the statements (in microns) are contained in Table I

Classification—Our flagellate belongs to the genus *Trimitus* Alexieff 1910, sp. typ. *Trimitus motellæ*, parasite of the intestine of the marine fish *Motella tricirrata*

TABLE I

No	Long axis	Breadth	Cercomonadic flagellum	Ant flagella	Nucleus
1	1·5	4	9½	5	1·5
2	3·5	2	7½	4	1
3	3	2·5	6	4	1
4	6	4	15	5	2
5	3	2·5	7	3	1

The characters of the genus *Trimitus* are two anterior flagella and one posterior, this one, thicker, of cercomonadic type, and with its axoneme crossing the body Nucleus anterior, subterminal, one basal granule giving rise to the three flagella

The other peculiarities which we find in Wenyon[1] describing the *Trimitus motellæ*, such as the length of the posterior flagellum, 4 to 5 times longer than the body and that of the anterior flagella, one of which has the same length as the body and the other, half of this length, must be considered as specific characters of *T motellæ*

We do not attach also great importance to the number of the basal granules In many of these small flagellates, we have seen that such organelles, even when seen under the appearance of one unit are, in reality, provenient of the fusion of more than one basal granule, their anatomic independence being often seen only in mitotic phenomena.

In 1919 Chalmers and Pekkola[2] described under the name of *Dicercomonas soudanensis*, renamed afterwards *Diplocercomonas sudanensis*, a flagellate in human fæces much similar to *Trimitus* Wenyon[1] having examined the original films of those authors, states that they were either *Embadomonas intestinalis* Wenyon & O' Connor (1917), either *Tricercomonas intestinalis* W & O Con , 1917 If these statements are correct *Diplocercomonas* becomes a ***nomen nudum*** If Chalmers and Pekkola are right in their description, *Diplocercomonas* becomes a synonym of *Trimitus*

The generic name *Trimitus* must be defined in the *Sensu* Alexieff (1910) and not in the meaning which was given to it by Duboscq and Grassé in 1923[3,4] The so-called *Trimitus* of these French authors has been shown by Kirby Jr[5] and de Mello[6] to belong to the genus *Tricercomitus* Kirby (1930)

The species we are describing now constitutes the second one belonging to the genus *Trimitus* We dedicate it to Dr U Rama Rau, the distinguished Director of the "Antiseptic" from Madras and President of the Legislative Council of that Presidency It will be named, therefore, *Trimitus ramaraui* n sp

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ON THE NECTAR SECRETION IN THE COCONUT FLOWERS (*COCOS NUCIFERA*, LINN.)*

By G V Narayana, B Sc (Ag)
(From the Agricultural Research Institute, Coimbatore.)

Received June 16, 1937
(Communicated by Dr J S. Patel, M SC, Ph.D.)

Since the floral nectaries have an important bearing on the mode of pollination, the study of the nectar secretion in the coconut flower was pursued Petch (1913) has recorded the secretion of nectar from three nectaries at the base of the teeth of the pistillode He has also mentioned the existence of numerous pores which exude a sweet fluid Sampson (1923) has observed that stigmas when receptive "have a sticky viscous surface in the triradial opening and that honey is secreted by glands at the base of the ovary whose ducts open near the apex of the fruit coat" Huggins (1928) has also observed the presence of nectaries in both the male and the female flowers Marechal (1928) has recorded the secretion of a sugary fluid from the numerous pores situated round below the stigmas In the course of the work carried out in this laboratory (Patel, 1937) the presence of three intercarpellary channels which themselves secrete honey was revealed

Material and Methods

Male and female flowers in the ordinary tall type of palms under observation were removed from the floral axis at the time of honey secretion The ovary was fixed in small pieces, but the pistillodes from male flowers were fixed *in toto* Formalin-acetic-alcohol was used for killing and fixing After washing in water, dehydrating in graded series of alcohol and clearing in grades of xylol or chloroform, the material was infiltered with and embedded in paraffin in the usual way. Serial sections 10–15 μ were cut from the base to the stigma of both the ovary and the pistillode Sections were stained with safranin and Delafield's hæmatoxylin, and safranin and light green Suitable Wratten 'M' filters and point light were used in taking photomicrographs; uniformity of focus in the field was obtained by the use of photo-eyepieces (Zeiss). Freehand sections were made use of extensively for rough examination

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* Contribution No. 5 of the Oil Seeds Section, Department of Agriculture, Madras.

Observations

Male Flower.—A clear, sweet fluid is secreted from the triradial opening of the pistillode teeth when the flower opens. The test with Fehling's solution revealed the presence of sugars in the fluid Secretion is more profuse towards the evening A delicate scent is also perceived Bees and ants are some of the more frequent insect visitors

Serial sections of the pistillode cut from the bottom to the top just at the time when the secretion occurs, reveal three intercarpellary or septal glands They are narrow, short and free at the base of the pistillode but meet a little way up in the centre and appear like one entire structure with three radiating branches, corresponding to the three carpels of the pistillode (Fig 1) The secreting surface consists of a closely packed palisade-like cells with rather large nuclei, dense granular cytoplasm and thin walls The gland increases in breadth radially and extends upwards to the bases of the pistillode teeth where it opens between the teeth (Fig 2) in the triradial orifice

Female Flower—After all the male flowers are shed, the female flowers become receptive. The stigmatic region emerges out of the perianth lobes As the stigmas become receptive, a sweet fluid collects on their inner surfaces. A little below the stigma, there are three orifices (Fig 6, no 9) 1-2 mm long Each orifice (Fig 6, no 9, Fig 3) is a minute opening alternating with a stigma Sometime after the stigmatic secretion commences a large drop of nectar collects at each of these three orifices

Freehand sections showed the nectar oozing from three different centres within the ovary (Fig 4) Each secreting area is situated in between the margins of carpels in a line with each of the arms of the central radial canal (Fig 5) Secretion is most profuse midway between the stigmas and the base of the ovary, and it is very scant (1) in the region of the ovules and (2) in the region between the stigmas and the orifices It is completely absent at the base of the ovary below the ovules

Sampson makes mention of three honey glands at the base of the ovary, the " ducts " of which open near the apex of the epicarp In view of the work reported in this note, it is clear that there are no glands at the base of the ovary and the " ducts " are the nectaries.

The course of the septal glands is indicated in Fig 6 The shape of the gland is like a canal or duct branched and compressed laterally. It is narrow at the upper and lower extremities but broad about the middle (Fig 6) Near the orifices, the glands take a very superficial course and are, therefore, indicated by slightly swollen streaks on the pericarp

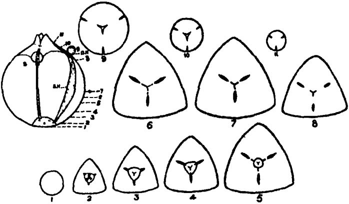

Fig 6.

extending to the stigmas The gland is lined by closely packed palisade-like secreting cells, as in the male flower and surrounded by a tissue of parenchyma (Figs 7, 8) The nectar from these glands oozes out through the three orifices, mentioned above

The stigmatic secretion which starts a little earlier than that of the septal nectaries is effected by the epidermal cells of the inner face of the stigma The triradial canal (Fig 5) in the centre of the ovary where three carpels meet and which extends from the stigma to the ovule bearing region at the base of the ovary does not appear to take part in secretion

Petch has mentioned the presence of numerous pores below the stigma "The position of the pores is indicated by whitish spots" round about the base of the stigma Microscopic examination of this region shows a large number of closely packed needle-shaped crystals (calcium oxalate) in shallow depressions on the epidermis, which is provided with secretory cells (Fig 9) These cells exude a liquid which on drying leaves incrustations of crystals

The inner tissue of this region is made up of a mass of parenchymatous cells with a number of scattered, young vascular strands without any secreting elements But the epidermis consists of closely packed, conspicuously elongated cells. These belong to the category of trichome type of multi-cellular hydathodes each consisting of a group of 4 to 16 cells, with a narrow base, round head and thick outer wall

Petch has further recorded that the secretion from these "pores" (which are now found to be the secreting elements) forms a ring of liquid preventing the ants from reaching the stigma In the material examined in the present investigation, this exudation was found to occur long before the stigmas became receptive The liquid had evaporated and minute deposits of crystals (white specks) were found a week prior to the opening of the stigmas It is, therefore, very likely that under South Indian conditions the ring of fluid does not exclude the ants from the work of pollination

Discussion

Knuth (1909) has stated that the species of genus *Cocos* are anemophilous, but the subsequent investigators have recognized the importance of insects in addition to wind as pollinating agents in the coconut The secretion of nectar by the male and the female flowers as also the sweet scent of the inflorescence show that the flowers are particularly adapted to attract insects But there seems to be a difference of opinion as regards the part played by ants in pollination Petch and Huggins have rejected the possibility of ants acting as agents in pollination, because of their inability to cross the ring of sweet fluid and reach the stigma It has been shown that the ring of liquid disappears long before the stigmas become receptive Furtado (1923–25) has shown that ants do help in the pollination of the coconut flower Kidavu and Nambiar (1925) observe that ants very probably help in transferring pollen

Septal glands similar to those found in the coconut flowers are reported to occur in ***Lilifloræ*** and ***Scitamineæ*** Haberlandt states "The septal nectaries which occur among ***Liliforæ*** and ***Scitamineæ*** belong to the category of internal glands According to Grassman, they arise by the partial non-coalescence of the margins of adjacent carpels When fully developed they consist of branched or unbranched canals and crevices in the substance of the pericarp, lined by papillose or palisade-shaped secretory elements Special outlets are provided for the escape of nectar" The "remarkable extra-nuptial nectaries" found at the base of the petiole in the genus ***Fagrea*** has, according to Haberlandt, some points in common with the septal nectaries Here the "palisade-shaped secretory cells enclose a cavity which ramifies more or less extensively in the substance of the leaf and opens outside by a passage" The septal or intercarpellary nectaries of the coconut are exactly like those of ***Liliforæ*** and ***Scitamineæ*** quoted above and bear a remarkable likeness to the extra-nuptial gland in *Fagrea* figured by Haberlandt.

Eames and Mac Daniels say "that the secreting cells of the stigmatic surfaces are of the same nature as those of nectaries . . . In all probability the majority of the nectaries are phylogenetically derived from hydathodes" This would mean that the secreting cells of the stigma and nectaries, and hydathodes are closely allied Thus in the coconut the secretory cells of (1) the septal nectaries, (2) the base of the stigma, and (3) the stigmatic surface, may be essentially of the same origin though of different shape and size That the secretory cells of the stigma, and the hydathodes are of epidermal origin is obvious from their position As regards the septal nectaries it may be seen that since they arise by partial non-coalescence of the margins of adjacent carpels they also are of epidermal origin

Summary and Conclusions

(1) Septal nectaries and hydathodes are for the first time reported in the coconut

(2) Nectar is secreted by the stigmatic surface and by three septal nectaries which are provided with outlets below the stigma There are no secreting glands at the base of the ovary

(3) The epidermal hydathodes exude a liquid in the region below the stigma Under South Indian conditions, in the tall type of palms, this exudation occurs before stigmatic receptivity, and does not exclude ants from reaching the stigma

(4) In the male flowers also the secretion of nectar is effected by septal nectaries situated in the pistillode

The author's thanks are due to Dr J S Patel, the Oil Seeds Specialist, for much valuable guidance during the course of the work

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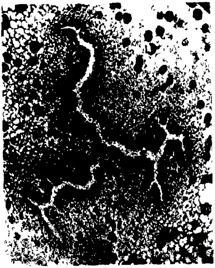

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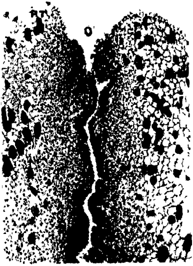

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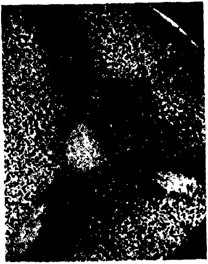

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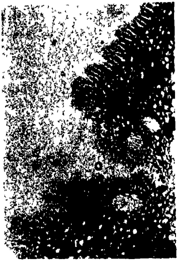

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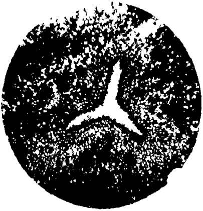

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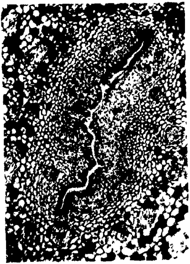

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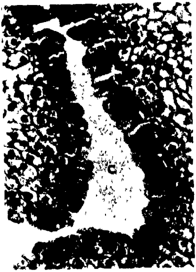

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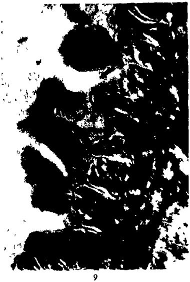

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LIST OF ILLUSTRATIONS.

Fig. 1 T S of pistillode showing three septal nectaries meeting in the centre. C Cavity. × 75

Fig 2 L S of pistillode showing one nectary with the outlet O between the pistollode teeth P T × 80

Fig 3. T.S of part of ovary at the time of secretion showing orifice O and epidermal hydathodes. × 100.

Fig 4. T S. of ovary showing three septal nectaries N. × 11

Fig 5 T S of ovary showing the central triradial canal × 55.

Fig. 6. Ovary—diagrammatic representation of the course of septal nectaries × 1

Fig 7. T S of a septal nectary of the ovary C, cavity ; S S, secreting surface, P., parenchyma of the nectary. × 84.

Fig. 8 T S. of part of septal nectary of ovary C, cavity, S S, secreting surface, P., parenchyma. × 320

Fig. 9. T S of ovary (part of) below stigma showing epidermal hydathodes E H and bundles (broken) of crystals, B C. × 330.

A NOTE ON APLANOSPORES IN A SPECIES OF *OEDOGONIUM*.

BY M. S. RANDHAWA, M.Sc., I.C.S.,
Fyzabad

Received July 14, 1937.

IN 1928 Handa described certain spore-like bodies in a species of *Oedogonium* which he diagnosed as akinetes. The present author also came across such bodies in a fertile species of *Oedogonium* last year.

These spore-like bodies are 20-24 μ broad and 30-72 μ long, and are obovoid in shape. Unlike those observed by Handa, these bodies were

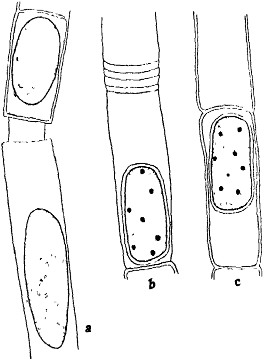

FIG. 1.—Aplanospores in a species of *Oedogonium*.

(*a*) Shows two recently divided cells with aplanospores, (*b*) and (*c*) Thick-walled aplanospores in vegetative cells. All × 660.

always found singly inside each cell and never in pairs. In some cases they have a thick walled covering (Figs *b* and *c*), and in one case where these were found inside two recently divided cells, the covering wall was very thin (Fig *a*)

The morphology and origin of these spore-like bodies is interesting Handa collected his material from a hilly place in southern Shan States of Burma, and surmised that a high altitude with its accompanying low temperature may influence their production. The material described in this paper was collected from the plains of the Punjab from a pond in Hoshiarpur District in the month of March 1930. So by no stretch of imagination can one ascribe their formation to low temperature and high altitude

In the chapter on "Vegetative and Asexual Reproduction of Oedogoniales" in his *Structure and Reproduction of the Algæ*, Fritsch states in a foot-note, "Handa's record of such stage (*referring to resting cells*) is open to doubt, as the presence of a parasite is to be suspected" As to what the grounds are on which such a suspicion is based, none are given Chytridiaceous fungi which are common parasites of some species of *Spirogyra* and *Oedogonium*, are usually globular in shape and much smaller in size. None of these fungi were noticed in the present material. So to call these spore-like bodies as fungi or to suspect their origin due to fungal organisms seems rather far fetched

How far is it right to call these bodies as akinetes is also open to doubt Akinetes are usually produced by the transformation of whole cells by the secondary thickening of the cell-wall as in *Pithophora*, *Oedocladium* and *Zygnema giganteum* In this case these spore-like bodies are formed inside individual cells by the rounding off of the contents and not by the thickening of the walls of the mother cell. Most probably these are zoospores, which having been unable to escape due to certain circumstances, have lost their flagella and developed thick walls. This is apparent from their resemblance in shape with immature zoospores as seen in Fig *a*. Hence it is more appropriate to call these bodies as "Aplanospores" rather than "Akinetes". As to whether these aplanospores are capable of germination and producing new individuals can only be found by further observations and experiments

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PALÆONTOLOGICAL STUDY OF GASTROPODS FROM LAKI AND BAGATORA, SIND.

By Raj Nath, M Sc , Ph D (Lond), D I C.

AND

G W Chiplonker, M Sc

(*From the Department of Geology, Benares Hindu University*)

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I Short History and Introduction

Before the extensive survey of Sind by W T Blanford[4] and Fedden in 1872-74, the stray collections of fossils made by Blagrave and by Capt Vicary were described by d'Archiac and Haime,[2] who had assigned a lower Tertiary age to all the Tertiary formations of Western India Later work, however, by Prof Jenkins[17] on *Vicarya verneuili*, and the associated forms definitely proved the existence of Miocene beds in Sind

Of the large collection of fossils made by Blanford and Fedden, during their survey, the Foraminifera were worked out by Prof R. Jones , Corals were studied by Duncan ,[14] while the Echinoids and Mollusca were provisionally identified by Blanford and Fedden—Echinoids were revised by Duncan and Sladen,[15] and the Mollusca were described by Cossmann and Pissarro,[16] Vredenburg[37-45] and Douville [12,13]

With the idea of doing more detailed and systematic stratigraphical work on lithological and palæontological bases, a large collection of fossils was made, bed by bed, from the neighbourhood of Bagatora (lat 26° 21′ long 67° 55′) and the dome north-west of the village of Laki (lat 26° 16′ long 67° 57′) *

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* The collection party consisted of the late Prof. K. K. Mathur and Messrs. G W. Chiplonker, M L. Misra and V. Bhasker Rao.

N B.—The following general sequence in the tertiary formations of North-Western India is given for the sake of convenience.

Manchhar Series	Upper	Lower Pleistocene
	Lower	Upper Miocene.
Gaj Series		Burdigalian
Nari Series	Upper	Aquitanian.
	Lower	Stampian
Kirthar Series	Upper	Upper Lutetian and probably Bartonian.
	Middle Lower (absent in Sind)	Lower and Middle Lutetian.
Laki Series	Laki Limestone Meting Shales Meting Limestone Basal Laki Laterite	Ypresian
Ranikot Series		Landenian.

ERRATA.

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Page 232, line 21—

for Vredenburg[37–45] *read* Vredenburg[39–45]

Page 246, Species No 64—

for ***Magnasperula***, Sacco, var ***bagatorensis***, var nov
read ,, ***magnasperula***, Sacco, var ***bagatorensis***, var nov

The present paper is intended to communicate the results of the palæontological study of Gastropods from the two above-mentioned localities Other groups of fossils represented in the collection are Foraminifers, Corals, Echinoids, Lamellibranchs, Nautiloids, vertebrate teeth and bones and silicified wood

II *Description of Species*

Family TURRITIDÆ, H and A Adams

Genus TURRICULA, Herrmann, 1783

Turricula lakiensis, sp nov

Pl XVI, Fig 1

The solitary specimen has a rather slender spire with three whorls, shouldered at a little distance from the posterior margin Height of spire whorls is about two-thirds of the width Posterior to the shouldering the whorls are nearly flat, and convex anteriorly

Ornament consists of prominent axial ribs, seven or eight per whorl, crossed by spiral threads alternating in two sizes

Body whorl is large and much inflated, and passes through a slight concavity, into the terminal stem (terminal portion of the body whorl was slightly damaged due to scraping before the specimen was photographed)

Aperture is angulated posteriorly to the shouldering Anteriorly, the outer lip runs nearly vertical and suddenly turns towards the terminal stem, giving to the aperture an elongate ovate outline Height of the aperture is about two-thirds of that of body whorl The inner lip is well defined, rather thin and deflected to the left at the beginning of the posterior canal

Height of the spire .	18 mm
Height of the body whorl .	26 ,,
Width of the body whorl	17 ,,
Height of the aperture	17 ,,
Width of the aperture . .	11 ,,

Comparison —Very close resemblance is offered to the present specimen, by *Surcula (Pleurofusia) scala*, Vred , Var ? from the Miocene of Myanktin, Burma,[7] but the Sind fossil differs in having a shorter spire, the penultimate whorl markedly smaller than body whorl and the inner lip receding to the left a little sooner

Occurrence —The middle division of the Upper-Middle Kirthar of Laki-Dome, north-west of Laki village.

Family CONIDÆ, Adams

Genus CONUS, Linnæus, 1758

Conus vredenburgi, sp nov

Pl XVI, Fig 2

The conical spire shows three or four whorls with height about one-fourth of their maximum width, corresponding with the anterior margin Spire angle is about 63° Whorls are angulated anteriorly at about one-third height Region anterior to the angulation is sub-vertical, while the posterior region is conspicuously concave The slightly raised posterior margin and the angulation give the appearance of two closely situated cords winding round the spire upto the apex This two-cord structure is likely to suggest six or eight spire whorls On the concave posterior slope, fine, crowded growth-lines are concave forward They are antecurrent to the angulation and retrocurrent to the posterior margin They give to the angulation and to the posterior margin an aspect of a row of scaly plates facing backwards

Body whorl is conical with feeble convexity Here the growth lines are convex forward Anteriorly to the angulation, body whorl is decorated with rather broad, almost flat, ribbon-like spiral threads alternating in two sizes to which the fine growth-lines give a rope-like appearance Angle of the body whorl is about 19°

Comparison —Due to the two-chord aspect of the spire-whorls, the present species resembles *Conus* (*Leptoconus*) *brochii* (Bronn)[29], the latter has, however, wider spire angle, taller spire, wider angle of the body whorl and no rope-like decoration on the body whorl

Occurrence —Middle division of the Upper-Middle Kirthar of Laki-Dome north-west of Laki village

Family VOLUTIDÆ, Gray

Genus VOLUTA, Linnè, 1758

Voluta sp indet A

The two fragmentary specimens show a very low spire and the axial ribs of the body whorl, giving rise to prominent spines at the posterior margin These specimens show some resemblance to the Alpine *V baricorum*, Oppenheim,[3, 6] which however, has a slightly taller spire

Occurrence —Nari Zone 4 B and 4 A of the hill west of Bagatora Railway Station

Family CYMATIIDÆ

Genus SASSIA, Bellardi, 1871

Sassia indica, Vred var *bagatorensis*, var nov

Pl XVI, Fig 9

This variety differs from Vredenburg's species[43] in having nearly twice (*i e*, 22 to 24) as many axial ribs as the species is described to have

Occurrence —Nari Zone No 2, from hill west of Bagatora

Family CASSIDIDÆ, Adam

Genus CASSIDARIA, Lamarck, 1812

Cassidaria archiaci, Coss and Piss

1853 *Cassidaria carinata*, Lamarck, *Descr an foss gr Num Inde*, p 317, Pl XXXI, Fig 1

1909 *Cassidaria archiaci*, Coss and Piss, *Pal Ind*, *n s*, Vol III, Mem No 1, pt 1, p 39, Pl IV, Figs 8 and 9

1928 *Cassidaria archiaci*, Coss and Piss, *Pal Ind*, *n s*, Vol X, Mem No. 4, p 45

If the specimens, representing this species, from the Upper Ranikot series, the Laki Limestone and the Lower division of the Upper-Middle Kirthar be arranged in series their spire shows a progressive shortening as we come up to the younger formations

Occurrence —Laki Limestone and Lower division of the Upper-Middle Kirthar of Laki Dome, north-west of Laki village

Family APORRHAIDÆ, Philippi

Genus APORRHAIS, de Costa, 1778

Aporrhais lakiensis, sp nov

Pl XVI, Fig 5

The spire is slightly conoidal and rather short, about two-fifths of the total height, consisting of four or five slightly convex whorls Height of the whorls is about two-fifths of their maximum width, situated at the anterior margin Spire angle is about 75° Whorls are decorated with thick spiral threads nearly as broad as the intervening spaces

Dorsal ovoid bulge of the body whorl passes anteriorly into an excavation at the neck At a short distance from the posterior margin a prominent keel separates the posterior concave region, carrying thick spiral threads like those on the spire-whorls Anteriorly to the keel threads are spaced at about twice their width

At the narrow aperture the keel is turned suddenly towards the apex reaching a little beyond the posterior margin of the third spire whorl, thus showing the extent of attachment of its wing

Following are the dimensions of three of the specimens representing this species —

Total height	63 mm	75 mm	60 mm
Height of spire	25 ,,	35 ,,	23 ,,
Height of body whorl	45 ,,	50 ,,	40 ,,
Maximum width	38 ,,	43 ,,	37 ,,

Comparison —This species may resemble, at first sight, the Ranikot fossil *Chenopus dimorphospira*, Cossmann and Pissarro [10] But the latter has a narrower apical angle of about 43° and taller and fewer spire-whorls

Occurrence —Laki Limestone and Lower division of the Upper-Middle Kirthar of Laki Dome, north-west of Laki village

Family CERITHIIDÆ, Fleming

Genus CERITHIUM, Brug

Cerithium sp indet A

The three incomplete specimens have an apical angle of 16° or 17°, height of whorls is two-thirds of their width, sutures are situated in shallow sulcus Whorls are nearly flat and carry five granular spiral threads, sub-equal and sub-equally spaced, the anterior-most thread becoming a little prominent, two of the specimens show a feeble sixth thread near the posterior suture of the later whorls

Comparison —These specimens resemble *Cerithum vivarii*, mut ***alpinum*** from the Priabonien and Oligocene of the Alps [5] Better preserved material is, however, necessary to identify these specimens with any known species

Occurrence —Nari Zone, No 1 and No. 2, from hill west of Bagatora Railway Station

Genus BELLARDIA, Meyer-Eymer, 1870

Bellardia coxi, sp nov *

Pl XVI, Fig 4

1930 *Bellardia* (?) sp indet, *Pal Ind*, *n s*, Vol XV, pt VIII, p. 145, Pl XVII, Fig 9

The single available specimen has only three of the spire whorls and the body whorl Apical angle is 26° Height of the whorls is about two-fifths

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*** This species is named after Mr L. R. Cox who had first recorded it from Samana Range.**

of their maximum width corresponding with the anterior margin Whorls are nearly flat ornamented with sixteen axial ribs, much narrower than the interspaces on the later whorls, but equal to them on the early whorls, their number thus remaining constant throughout, ribs become less and less significant towards the later whorls Five spiral striations cross the ribs giving rise to feeble elongate nodes Posterior margin is immediately followed by a circumsutural ribbon formed by a narrow, shallow groove crossing the axial ribs

The convex base is much depressed and carries several spiral threads At about 200° from the aperture, there is a conspicuous varix, and another on the second spire whorl, the presence of varices on the intermediate portions cannot be ascertained due to hard incrustation

Remarks—This specimen is identical with the Samana Range fossil described by L R Cox, except the spire angle which is 29° in the latter This difference, however, would not separate Samana specimens from the present one

Occurrence—The Nari Zone No 2, from hill behind Bagatora Railway Station

Genus TYMPANOTOMUS, Adams

Tympanotomus sub-lævis, sp nov

Pl XVI, Fig 8

The shell is moderately sized, scalariform with apical angle measuring 22° Whorls are one-third as high as their width, and carry two prominent spiral threads; alternating with these on their anterior side are two threads of a little lesser significance, while a still finer thread passes medianly Posterior margin of the whorls consists of a broad band twice as broad as the prominent threads

Comparison—This species differs from the associated *T lævis*, Vred "by the number, the disposition and the degree of differentiation of the spiral threads, as also by its wider apical angle

Occurrence—Nari Zone No 2, from hill behind Bagatora Railway Station

Family TURRITELLIDÆ, Gray

Genus TURRITELLA, Lamarck, 1799

Turritella magnasperula, Sacco, var *bagatorensis*, var nov.

Pl XVI, Fig 3

Shell has a fairly steep apical angle Height of the whorls is a little more than half their width The sub-vertical anterior part of the whorls carries three (or four) very prominent threads, posteriorly to these is a region of fair width Here due to unfavourable preservation it is difficult to observe any ornamentation Region posterior to this carries five or six spiral threads which are of lesser significance and also more close-set than those of the anterior region After this a short slope reaches upto the suture, a corresponding but wider slope near the anterior margin carries two threads sub-equal to those of the posterior region

Comparison—From *T magnasperula sacco* var *crassocingulata* Vred[44] The present specimens differ in having three or four prominent threads in the anterior region, wider apical angle, two threads on the anterior slope and five or six threads on the posterior region of the whorls

Occurrence—Nari Zone No 1 and No 4 C, from hill behind Bagatora Railway Station

Turritella sindiensis, sp nov

Pl XVI, Fig 6

The shell is fairly stout, with apical angle measuring 20° or 21° Height of the whorls is about half the greatest width corresponding with the anterior keel situated at one-third the height of the whorl A smaller keel passes at about two-thirds the height of the whorl The slopes flanking both the keels are feebly convex, except immediately at their bases where they are sharply concave a thread passes close to this concavity Both the margins have a spiral thread closely following them Sutures are deeply incised The shell gives the general appearance of a Pagoda

Comparison—This species has a very characteristic appearance, but when ornamentation is effaced, it might resemble *T. ranikoti* Vred var. *leilanensis*, Vred.[44] from Upper Ranikot beds, the present form, however, has a wider apical angle, the region between the two keels slopes posteriorly and carries no threads, while the corresponding region in the Ranikot fossil is concave and carries three spiral threads

Occurrence—Nari Zone No 1, No. 2 and No 4 B, from hill west of Bagatora

Genus MESALIA

Mesalia tricarinata, sp. nov.

Pl XVI, Fig. 7.

The shell is stout, the spiral angle measuring 20°. Whorls are strongly convex, with height about two-thirds of their maximum width corresponding to the median spiral thread. Sutures are deep Whorls carry three prominent threads almost like keels, equal and equally spaced from suture to suture. The concave intervals carry two to four very fine intercalary threads. The convex base carries two threads additional to those continued from the spire whorls Aperture is sub-circular to oval.

Comparison—This species resembles *Mesalia cochleata*, (Br) var *crassocincata*, Sacco[1, 20] The latter, however, has its whorls less convex, sutures a little shallow, narrower apical angle, and spiral threads more numerous and differentiated *Mesalia faciata*, Lamarck, from the Cardita Beaumonti beds,[12, 13] has its whorls much less convex

Occurrence—Nari Zone No 1, No 2 and No 4 C, from hill west of Bagatora

Family EUSPIRIDÆ

Genus AMPULLINA, Lamarck, 1821

Ampullina, sp indet A

The two fragmental specimens representing this species have a large sub-oblate body whorl, with the greatest convexity nearer the posterior margin than the anterior extremity As judged from the disposition of the more or less flat penultimate whorl, the spire should be rather low and depressed with wide apical angle Aperture is sub-circular The callus "limb" is not clearly seen

Comparison—In general aspect these specimens resemble the Priabonien and Bartonian Alpine fossil *Natica* (*Ampullina*) *picteti*, Herbert and Renevier[8] from which they differ by shorter (?) spire, a smaller sub-angulated aperture, more depressed whorls and more inflated body whorl

Occurrence.—Nari Zone No 2 and the upper division of the Upper-Middle Kirthar of the hill west of Bagatora

Family EPITONIIDÆ

Genus EPITONIUM, Bolton, 1798

Epitonium mathuri, sp nov *

Pl XVI, Fig 10.

A single specimen represents this species It has five strongly convex whorls, about half as high as their maximum width situated medianly The slightly oblique, acute axial threads are thirty or thirty-two per whorl The seven spiral threads, of about the same magnitude, as the axial ones, are equally spaced from suture to suture, and give rise to minute tubercles at points of their intersection with axial threads Fine spiral intercalary threads bisect the spiral intervals, which are narrower than the axial ones. Sutures are deeply incised Spiral angle measures 18°

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* This species is named after the late Prof. K. K Mathur.

Comparison —*Scala gajensis* Vred [44] from the Gaj Beds of Kachh differs from the present species, in not having the spiral threads, while *Scala sub-tenuilamella*, d'Archiac and Haime,[3,44] from the Gaj Beds of Sind has its whorls angulated, a smaller apical angle measuring only 14° and the spiral threads very feeble as compared to the prominent and more close-set axial lamellæ. Similar features and a still narrower apical angle excludes the Ranikot form *Scala* (*Acrilla*) *colpophora*, Coss and Piss [10] from consideration

Occurrence —Nari Zone No 4 B, from hill west of Bagatora Railway Station

III General Results from Palæontological Study

Table II, showing the stratigraphical distribution of the Gastropod species from Laki and Bagatora, shows that twenty-seven species are confined exclusively to the Laki and the Kirthar Beds, fifty-nine species are restricted to the Lower Nari Series, while ten species are common to the upper division of the Upper-Middle Kirthar and the Lower Nari Series Of these *Ampullospira* (*Euspirocrommium*) *Oweni*, d'Archiac and Haime and *Ampullina*, sp indet B, extend from the upper division of the Upper-Middle Kirthar upto the Nari Zone No 4 E, and *Turbinella*, sp indet A, ranges from the Laki Limestone upto Nari Zone No 2 But as these three species are represented by ill-preserved casts, they are left here provisionally as heterogeneous groups

As regards the zonal distribution of the Gastropod species in the Lower Nari Series, the Zone No 2 stands out very prominently by its richness in the Gastropod species Out of the fifty-nine species restricted to the Lower Nari Series, forty-three are represented here The next richest zone is Zone No 4 E, containing twenty-two species, the Zone No 4 B, with twenty-one species comes third Zone No 1 with twenty species and Zone No 4 C with thirteen species are moderately rich in Gastropod species, while Zone No 3, Zone No 4 A and Zone No 4 D are strikingly poor

Cerithium (*Ptychocerithium*) aff *perlamellosum*, Vred and *Trochus* (*Tectus*) *lucasianus*, Bron are confined to Zone No 1, Zone No 2 has sixteen species confined to it while three species are common to Zone No 1 and Zone No 2, seven species from Zone No. 2 are not represented in Zone No 1, but are continued into the upper zones, so that Zone No 2 can be taken as a unit separated from Zone No 1 on the one hand and Zone No. 3 on the other Now Zone No 3, Zone No. 4 A and Zone No. 4 D do not call for any special treatment due to their conspicuous poverty in Gastropod species. The Zone No 4 B out of its twenty-one species has five species exclusively confined to it, while only one species it has in common with Zone No 4 C and three species from it reach up to Zone No 4 E, on the other hand, four species are common to Zone No 4 B and Zone No 2 Out of the twenty-two species represented in Zone No 4 E seven are restricted to it

From the foregoing discussion it can be concluded that the Lower Nari Series, on the basis of vertical distribution of the Gastropod species, can be divided into Zones No 1, No 2, No 3, No 4 A, No 4 B, No 4 C, No 4 D and No 4 E

From Table I, showing the zonal sequence in the Lower Nari Series as observed in the field on lithological basis, it can be seen that the thick variegated layers of shales and sandy shales constitute a very prominent feature in the field, separating the three lower zones from the top zone (consisting of five sub-zones) The shale beds intervening between the lower three zones are less sandy and are not as thick as those underlying zone No 4, but are too conspicuous to be overlooked in the field in comparison with the thin but highly fossiliferous beds of limestones, on the other hand, the shale beds intercalated with the five sub-zones, of Zone No 4 are not so prominently thick, as compared to the fossiliferous limestone beds, and yet they cannot be missed in the field

Thus the zonal sub-division of the Lower Nari Series as arrived at on the basis of the palæontological study of Gastropods is in full agreement with the one adopted in the field on the basis of lithology A preliminary study of the Nummulites, Corals and Echinoids also suggests similar results

As mentioned above, fifty-nine species are restricted to the Lower Nari Series, and ten species, it has in common with the upper division of the Upper-Middle Kirthar Among the former group, there are thirteen species which are new occurrences to the Bagatora area, eight of these species are known to occur in Miocene beds of Sind,[43, 44] Kuchh,[43, 44] Kathiawar,[43 44] Baluchistan[43, 44] and Burma [19 30, 39] Thus Miocene affinities had begun to be manifest in the Nari fauna of Bagatora area This would suggest that the bright red to purple coloured, unfossiliferous, calcareous sandstones succeeding the Lower Nari Series at Bagatora[4] are very probably the representatives of the Gaj Series

In conclusion, the authors take this opportunity of expressing their indebtedness to Dr A Morley-Davies, lately of the Imperial College of Science and Technology, London, for his kind suggestions and valuable criticism. Thanks are also due to the Director, Geological Survey of India, for kindly lending the necessary literature from time to time and also for the access to the type specimens preserved in the Indian Museum, Calcutta.

TABLE I

Table showing the Zonal sequence of the Lower Nari Series as observed in the Field

Zones	Thickness	Lithological and faunal characters
No 4 E	1 ft	Brown shaly limestone breaking into thin slabs rich in flat Echinoids and Gastropods, Nummulites and Lamellibranchs are present in moderate numbers
Shales	1 to 2 in	Unfossiliferous, coloured brown
No 4 D	1 ft	Greyish brown limestone breaking into irregular blocks Rich in Nummulites, Gastropods, Echinoids and Lamellibranchs are not very abundant
Shales	1 to 2 in	Unfossiliferous, coloured brown
No 4 C	1 ft 3 in	Greyish brown limestone breaking into irregular blocks Moderately rich in Nummulites and Gastropods, poor in Lamellibranchs
Shales	1 to 2 in	Unfossiliferous, coloured brown
No 4 B	1 ft 3 in	Reddish yellow limestone breaking into thin plates Rich in Gastropods, Corals, Echinoids, Nummulites and Lamellibranchs are moderately represented
Shales	1 to 2 in	Unfossiliferous, coloured brown
No 4 A	1 ft 6 in	Yellowish limestone breaking into thick long slabs Poor in Gastropods; Nummulites and Lamellibranchs are represented fairly well
Shales	43 ft. 3 in	Unfossiliferous, coloured yellowish brown and containing gypsum
Sandy shales	9 ft	Unfossiliferous, coloured grey
No 3	3 ft	Yellowish brown limestone breaking into thick slabs Very poor in Gastropods, rich in Echinoids and Nummulites, Lamellibranchs and Corals are fairly represented.
Shales	35 ft	Unfossiliferous, coloured yellowish and pink
No 2	9 in	Greyish brown limestone breaking into thin slabs Rich in Nummulites, Gastropods and Corals; Echinoids and Lamellibranchs are present in moderate numbers
Shales	14 ft 10 in.	Unfossiliferous, coloured white, red, brown
No 1	2 ft	Brownish and yellowish limestone hard, rather compact and not breaking very easily Rich in Nummulites; moderately rich in Gastropods; Lamellibranchs and flat Echinoids are also present, tubes of *Teredo* are very common, occurring in all possible positions.

TABLE II

Table showing the Stratigraphical Distribution of Gastropods from Laki and Bagatora, Sind.

Species	Laki Lime-stone	Upper Middle Kirthar			Lower Nari Series							
		Lower	Middle	Upper	Zone 1	Zone 2	Zone 3	Zone 4 A	Zone 4 B	Zone 4 C	Zone 4 D	Zone 4 E
Order *Opisthobranchiata*												
1 *Acera narica*, Vred						1						
2 *Scaphander oligoturritus*, Sacco					? (2)	1						
Order *Prosobranchiata*												
3 *Turricula lakiensis*, sp nov			1									
4 *Conus* (*Lithoconus*) *brevis*, J de C Sow									2	2		
5 ,, ,, *ineditus*, Micht				2	1	2						
6 ,, *vredenburgi*, sp nov			2									
7 ,, sp indet		1										
8 *Oliva virginiae*, d'Archiac and Haime	2											
9 ,, (*Strephona*) *australis*, Duclos, var *indica*, Vred						2						
10 *Ancilla* (*Sparella*) *indica*, Vred									4			2
11 *Harpa* (*Eocithra*) *narica*, Vred												2
12 *Athleta* (*Volutospina*) *sindiensis*, Vred						?			2			
13 ,, ,, *dentata*, Sow, var *sykesi*, d'Archiac and Haime						1			9	1		1

TABLE II—(*Contd*)

Species	Laki Lime stone	Upper-Middle Kirthar			Lower Nari Series							
		Lower	Middle	Upper	Zone 1	Zone 2	Zone 3	Zone 4 A	Zone 4 B	Zone 4 C	Zone 4 D	Zone 4 E
14 *Voluta*, sp indet A								1	1			
15 ,, *multidentata*, d'Archiac and Haime	4	6										
16 ,, *salsensis*, d'Archiac and Haime	8	1	2									
17 ,, sp indet B	4											
18 *Lyria anceps*, Micht						1			4			
19. ,, *jugosa* (J de C Sow)												4
20 ,, *feddeni*, Vred	1											
21 *Vexillum* (?) sp indet	2											
22 *Fusus humei*, Vred			1	6								
23 *Euthriofusus subregularis* (d'Arch and Haime)						1						
34 *Lathyrus sindiensis*, Vred												1
25 *Turbinella* sp indet A	9	4		52	2	9						
26 ,, (?) sp indet B						5						
27 *Tritonidea* (*Cantharus*) *erythrostoma* (Reeve)												1
28 *Cominella anadalei*, Vred						1						
29. *Lacuna indica*, Vred				1								
30 ,, *manbuensis*, Vred				1								
31. *Murex* (*Haustellum*) *naricus*, Vred.						1						

32 *Bassa indica*, Vred var *bagatorensis*, var nov						1						
33. *Cassidea* (*Semicassis*) *oligocalanica*, Vred						4			1			
34. *Cassidaria archiaci*, Coss and Piss	1	1										
35. *Sconsia beyrichi*, Coss and Piss									1			
36. *Pirula condita*, Bron						10				1	1	
37 *Cypraea* (*Bernayia*) *sub-exisa*, Braun						10		1	9	1		4
38. ,, *prunum*, Sow var *nasuta*, Sow									7			1
39 ,, *sindiensis*, Vred						1			1			
40 *Gisortia* (*Vicetia*) *murchisoni*, Vred	8	1										
41. ,, ,, *depressa*, J de C Sow		2										
42 *Strombus*, sp indet				1								
43. *Rimella prestwichi*, d'Archiac and Haime	1	1	1									
44 *Terebellum* (*Seraphs*) *naricum*, Vred						3						
45 *Aporrhais lakiensis*, sp nov	5	5										
46 *Cerithium* (*Bellardia*) *naricum*, Vred												3
47 ,, (*Ptychocerithium*) *triangulatum* Vred												12
48 ,, ,, *ighinai*, Micht										2		
49 ,, ,, aff *per-lamellosum*, Vred					1							
50 ,, sp indet A					2	1						
51 ,, sp indet B					2	2						
52 ,, sp indet C				3	2	2						

TABLE II—(*Contd*)

Species	Laki Lime-stone	Upper-Middle Kirthar			Lower Nari Series							
		Lower	Middle	Upper	Zone 1	Zone 2	Zone 3	Zone 4 A	Zone 4 B	Zone 4 C	Zone 4 D	Zone 4 E
53 *Cerithium* sp. indet D						3						
54 ,, sp indet E				3		2						
55 *Bellardia coxi*, sp nov.						1						
56 *Tympanotomus laevis*, Vred						2						
57 ,, *sub-laevis*, sp nov						1						
58 *Campanile*, sp indet A	1											
59 ,, sp indet B	1											
60. *Pyrazus*, sp. indet	3											
61. *Turritella narica*, Vred.									3		2	8
62 ,, *pseudo-bandongensis*, Vred.												3
63 ,, *asperula*, Brogniart					3				1			1
64. *Magnasperula*, Sacco, var *bagatorensis*, var nov					1					8		
65 ,, *pseudo-tethys*, Vred									14			
66 ,, *bagatorensis*, Vred.									5			
67. ,, *ramkoti*, Vred. var *lailanensis*, Vred						1						1
68 ,, *tippers*, Vred.						1						
69 ,, *sindiensis*, sp. nov					1	2		2				
70. ,, sp. indet						2						

71. *Mesalia tricarinata*, sp. nov.					2	5				1		
72. *Protoma deshayesi* (d'Archiac)						13		2	14	2	1	41
73. ,, *renevieri* (d'Archiac and Haime)						2						3
74. ,, *retrodilatatum*, Vred					2	3			7			2
75. *Siliquaria granti*, J. de C. Sow.						2						
76. *Architectonica varica* (Vred.)					? (1)	5			3			1
77. *Natica angulifera*, d'Orb			1	1								
78. ,, (*Naticina*) *adela*, Coss and Piss.			6	28								
79. ,, ,, *longispira*, Leym.									1			
80. *Sigaretus*, sp indet				20	1	6		1		3	1	2
81 *Gyrodes*, sp indet A							1					
82 ,, sp. indet B				1	5							
83 *Ampullospira* (*Euspiro-crommium*) *oweni*, d'Arch and Haime				6	4	12				9		1
84. *Ampullina* (*Globularia*) *gibberosa*, Grateloup				2	2	13						
85. ,, *rouaulti*, d'Arch and Haime						3						
86 ,, *sigaretina*, Lamarck				3	1	3						
87 ,, sp indet A				1		1						
88 ,, sp indet B				18	1	12				11	1	4
89. *Epitonium mathuri*, sp nov									1			
90. *Velates schmidelianus*, Chemn	6	1										
91. *Turbo*, sp indet A										1		

TABLE II—(*Concld*)

Species	Laki	Upper Middle Kirthar			Lower Nari Series							
	Lime-stone	Lower	Middle	Upper	Zone 1	Zone 2	Zone 3	Zone 4 A	Zone 4 B	Zone 4 C	Zone 4 D	Zone 4 E
92 *Turbo*, sp indet B	1											
93 ,, sp indet C		1										
94 ,, sp indet D	1											
95 *Trochus* (*Tectus*) *lucasanus*, Bron					1							
96 *Tugurium sub-extensum*, d'Orb										3		1
Total Number of Species in each Bed	17	11	7	17	20	43	1	4	21	13	5	22

N.B—Numbers in the different columns indicate the number of specimens representing the species in the particular bed.

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EXPLANATION OF PLATE

FIG 1 *Turricula lakiensis*, sp nov, from the middle part of Upper-Middle Kirthar, near Laki, (B H U No G/148)

FIG 2 *Conus vredenburgi*, sp nov, from the middle part of Upper-Middle Kirthar near Laki, (B H U No G/141*a*)

FIG 3 *Turritella magnasperula*, Sacco, var *bagatorenesis*, var nov from Lower Nari Zone No 1, near Bagatora, (B H U No G/75*b*)

FIG 4 *Bellardia coxi*, sp nov., from Lower Nari Zone No 2 from Bagatora, (B. H U No G/94)

FIG 5 *Aporrhais lakiensis*, sp nov, from lower part of the Upper-Middle Kirthar near Laki, (B H. U No G/128*b*)

FIG 6 *Turritella sindiensis*, sp. nov, from Lower Nari Zone No 2 from Bagatora, (B H U No G/77*a*)

FIG 7 *Mesalia trikarinata*, sp nov, from Lower Nari Zone No 2 from Bagatora, (B H U No G/78*e*)

FIG 8 *Tympanotomus sub-lævis*, sp nov, from Lower Nari Zone No 2 from Bagatora; (B H U No G/93)

FIG 9 *Sassia indica*, Vred var *bagatorensis*, var nov, from Lower Nari Zone No 2 near Bagatora, (B H U No G/152)

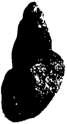
FIG 10 *Epitonium mathuri* sp. nov, from Lower Nari Zone No 4 B near Bagatora, (B. H U No. G/131)

N.B —All Figures are natural size

Fig 5 is a photograph from a drawing made faithfully to the Type specimen, except that the details are shown more clearly than on the weathered specimen itself.

Raj Nath and
G. W. Chiplonker

Proc. Ind. Acad. Sci., B, vol VI, Pl. XVI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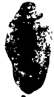
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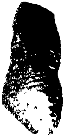
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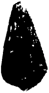
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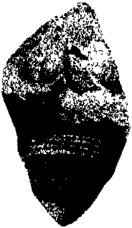

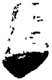
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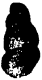
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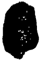

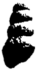
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ON THE ORIGIN AND DEVELOPMENT OF THE CEMENT GLANDS IN *ETROPLUS MACULATUS* (BLOCH).

By S. Jones

(From the University Zoological Research Laboratory, Madras.)

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Introduction

While engaged in working out the development of some brackish water fishes of Adyar,* I had the opportunity to investigate the development of the cement glands in two Cichlid fishes, *Etroplus maculatus* and *E. suratensis*. These glands have the same function as in the larvæ of Ganoids, Teleosts, Dipnoids and Anura in which similar organs have been discovered. The developmental origin of these larval organs has been worked out in the case of Ganoids, Dipnoids and Anura. In the first group they arise from the endoderm whereas in the latter two, they are of ectodermal origin (Kerr, 1919). Though cement glands are known to occur in some tropical Teleosts like *Etroplus*, *Pterophyllum*, *Sarcodaces* and *Hyperopisus*, no work on their origin has been done so far to my knowledge.† The present paper deals with the cement glands in one of the local forms, *Etroplus maculatus*.

These structures, found only in the aquatic larvæ of some fishes and amphibians, are all purely larval organs primarily concerned with the attachment of the larvæ to some foreign object to prevent their being swept away by currents. Except in the case of the larvæ of *Acipenser*, where they are transformed into barbels, the cement glands degenerate and disappear in course of time. In the case of *Etroplus* also the glands are most active during the earliest larval stage and then atrophy as soon as the young fish is capable of swimming about.

Historical

Ganoids.—It was Agassiz (1879) who first worked on the cement glands of fishes when he dealt with the function, degeneration and disappearance of the gland (suctorial disc) in *Lepidosteus*. He did not mention anything as to its origin. In 1881, Balfour dealing with the same form, considered the suctorial papillæ of the gland as epiblastic sensory thickenings and later in 1882, Balfour and Parker speak of them as modified cells of the mucous layer of the epidermis pouring out a sticky secretion. Phelps (1899) as a result of her work on *Amia calva* said that the gland is endodermal in its origin. Subsequently, Reighard and Phelps (1908) gave a detailed account of the origin and development of the gland in *Amia calva* and they attributed a similar (endodermal) origin to the gland in *Lepidosteus*. About the same time appeared the work of Eycleshymer and Wilson (1908) and these authors agreed with regard to the endodermal nature of the glands in *Amia calva*.

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Kerr (1906 and 1907) worked out the development of the gland in *Polypterus senegalus* (Budgett's collection) and found it to take its origin from the endoderm. He was not at the time aware of the work on *Amia calva* by Phelps. Kupffer (1893) thought that the cement organs of *Acipenser sturio* was of ectodermal origin. Sawadsky (1911) basing his work on *Acipenser ruthenus* said that the organ in question actually originates from the ectoderm. Thus the endodermal development of the cement glands in Ganoids was finally settled.

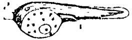
Dipnoids and Anura.—Among the Dipnoi cement glands are known to be present only in ***Lepidosiren paradoxa*** and ***Protopterus annectans***, where they have been found to be of ectodermal origin (Kerr, 1903 and 1919). Assheton (1896) and Bhaduri (1935) worked out their development in ***Rana temporaria*** and *R. afghana* respectively and found them to originate from the outer layer of ectoderm. The difference in these two groups is that in the Dipnoi the secretory cells of the glands develop from the inner layer of ectoderm whereas in the Anura they develop from the superficial layer of ectoderm.

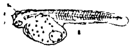
Teleosts.—Cement organs are known to occur only in a very few tropical Teleosts. It was first discovered by Budgett (1901) in the larvæ of two African fishes, *Sarcodaces odœ* (Characinidæ) and another which he provisionally determined as *Hyperopisus bebe* (Mormyridæ). Assheton (1907) when dealing with the sense organs and mucous canals in the larvæ of *Gymnarchus niloticus* and *Heterotis niloticus* mentions about the presence of mucus secreting glands on the head. It is possible that they are similar to the glands in *Hyperopisus* and *Sarcodaces* though Budgett who examined the living specimens did not observe any adhesive organs. Probably they are degenerate. They are known in some Cichlids like ***Etroplus suratensis*** (Willey, 1911), *E. maculatus* (Sundara Raj, 1916) and ***Pterophyllum eimekei***

(Lieberkind, 1931). Of these Cichlids the last one is South American and the other two are South Indian forms.

From the literature available it appears no work has been done so far on the origin of the gland in Teleosts. Lieberkind (1931) described the well-developed and active gland of the five days old larva of *P. eimekei* and mentions its absence in a 10 days old one. But due to lack of sufficient material he could not work out the origin of the gland.

Cement Organs of Etroplus maculatus.—In the case of this fish, as soon as it hatches out, the glands can be seen as three pairs of symmetrically arranged conical projections each with a depression at the top. One pair is situated at the anterior extremity of the head near the olfactory organs, whereas the other two pairs are found close together dorsal to the eyes (Figs. 1 and 2). These are larger than the anterior-most pair. The glands secrete mucus till the fourth day after which they become inactive and gradually atrophy. During this short period the secretion helps to keep the larvæ in one place under the care of the parents, thus affording protection (Fig. 3).





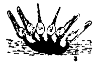


FIG. 1.—Newly hatched larva. × 22. 1, 2 and 3 = Cement organs.

FIG. 2.—Larva 2nd Day. × 22.

FIG. 3.—A group of young larvæ resting at the bottom attached by their mucous threads. × 6.

Origin and Development.—The cells of the gland rudiment gradually become distinct in the thirty-eight hours old embryo. The rudiment develops as a thickening of the inner layer of ectoderm (Fig. 4). The cells are long and conical with the nuclei at their base. They soon curve over enclosing a space, the gland cavity, roofed over by the thin superficial layer of ectoderm Fig 5 is a transverse section of the head passing through the middle pair of glands in a fifty-four hours old embryo

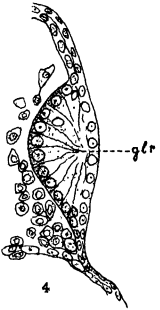
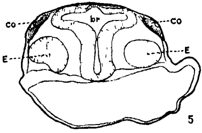


FIG. 4—Section through a gland rudiment of a 38 hours old embryo *glr*, gland rudiment

Hatching takes place seventy-two hours after fertilization at which time all the three pairs of glands are active The secretion of the gland cells fills the cavity and bursts open the superficial layer of ectoderm which gets peeled off Now the cavity widens This is accompanied by the raising of the sides of the cavity which results in the formation of a deep gland cavity opening to the outside The superficial layer of ectoderm extends up to the edge of the gland cup (Fig 6) No "brush border" of the kind mentioned by Bhaduri (1935), lining the gland cells in ***Rana afghana***, has been observed

Several larvæ are found anchored to one place by mucous threads emanating from the cement glands The parents have, as has been already observed, the curious habit of transferring their broods from place to place and each time, the young ones attach themselves once more by mucous threads In the attached condition the larvæ remain with the dorsal surface of the head touching the substratum with the body held at an angle to the ground and the tail vibrating incessantly When disturbed they break off from their moorings and move off in this characteristic position trailing a quantity of dirty mucus behind them They again collect together in groups and a fresh attachment is effected



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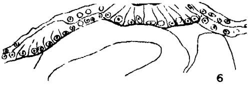

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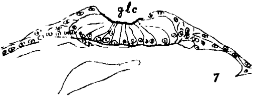

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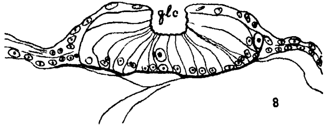
Fig 5 —Section through the head of a 54 hours old embryo passing through the middle pair of cement glands

Fig 6 —Section through the cement organ 1st Day × 380

Fig 7 „ „ „ „ 2nd Day × 380.

Abbreviations *br*, Brain, *co*, Cement Organ, E, eye, *glc*, Gland cavity

The glands grow in size (Figs 7 and 8) Meanwhile the interspace between the pairs of glands increases Gradually, they get flattened out and the cells become vacuolated The cell walls become indistinct and degeneration sets in The rapidity of the process can be understood by the change the glands have undergone by the fifth and the sixth day (Figs. 9 and 10). As soon as they shrink in size the superficial layer of ectoderm from the sides, which at this time gets considerably thickened, grows over the rapidly degenerating structures which are soon lost By the seventh day it is hardly possible to locate their position



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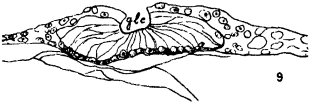

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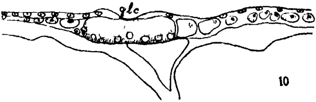

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Fig 8.—Section through the cement organ 4th Day. × 380
Fig. 9 " " " " 5th Day. × 380
Fig. 10. " " " " 6th Day. × 380.

The structure and position of the cement glands of *E suratensis* are exactly as in *E maculatus* Though their origin and development have not been worked out it is not likely that there will be any difference

The following table gives the origin and fate of the cement organs in the vertebrates in which these structures have been studied

Group	Genus	Origin	Fate
Ganoidei .	*Amia*	Endodermal	Disappear
	Acipenser	,,	Transformed into barbels
	Lepidosteus	,,	Degenerate
	Polypterus	,,	Disappear
Teleostei .	*Etroplus*	Ectodermal (Inner layer)	Disappear
Dipnoi .	*Protopterus*	Ectodermal (Inner layer)	Disappear
	Lepidosiren	,,	,,
Anura .	*Rana*	Ectodermal (Outer layer)	Disappear

Discussion

The present work has shown that the cement organs of *E maculatus* take their origin from the inner layer of ectoderm The condition is similar to that in the lung fishes, *Protopterus* and *Lepidosiren*, but differs from the cases described in Anura where the glands develop from the superficial layer of ectoderm

In the case of *Hyperopisus bebe* and *Sarcodaces odæ* the two African fishes described by Budgett, the former has three pairs of cement glands as in *Etroplus* and the latter a large single median one on the dorsal side of the head The larvæ in both cases hang suspended by mucous threads secreted by the cement organs The arrangement and structure of the glands in active condition of *Pterophyllum* are exactly as in *Etroplus* Both behave in a similar manner by resting at the bottom As they belong to the same family, Cichlidæ, in all probability, the origin of the organs is the same.

The fact that the cement organs are meant solely to help the animals to attach themselves to some object without being carried off by water currents, shows why they are found only in the aquatic larvæ of vertebrates and not in those of terrestrial ones, where we find all traces of them omitted in their ontogeny Only very rarely do we come across fishes having these structures Among the Amphibians the larval Anura generally possess them They are completely unrepresented in the Cyclostomes, Elasmobranchs and Apoda and absent in their typical form in the Urodela But in the last group, many possess two rod-like structures one on either side, known as balancers, the true homology of which is doubtful They have glandular tips and develop as ectodermal projections from outside the mandibular arch and serve as organs of support and attachment (Harrison, 1925) A branch of the hyoidean artery supplies these structures and the blood is returned to the jugular veins (Maurer, 1888) Goodrich (1930) has suggested that the balancers are homologous to the cement organs of Anura and judging from their development, function and early atrophy, one is disposed to accept this view The stalked condition will have to be considered as a secondary feature developed in the course of evolution This does not appear in any way improbable when we find the cement organs of larval *Acipenser* getting modified into barbels in the adult Also, just as the cement organs degenerate in fishes when the pectoral fins are developed, the balancers of Urodeles atrophy as soon as the fore-limbs are sufficiently developed to support the head

The origin of the cement organs as endodermal pouches in the Ganoidei has led Kerr (1906) to compare them with the pre-mandibular head cavities of other vertebrates Reighard and Phelps (1908) are of opinion that these glands are homologous with the anterior gut pouches of Elasmobranchs, which in turn, have been homologized with the anterior gut pouches of Amphioxus, one of which is converted into the ciliated organ (Neal, 1898 and van Wijhe, 1914) It is very doubtful if this view could be accepted from the fact that in the Teleostei, Dipnoi and Anura these organs are of ectodermal origin, though the condition in Ganoidei is in support of it This would mean that the organs have arisen independently in the different groups of vertebrates as suggested by Eycleshymer and Wilson (1908) who also support the suggestion of Balfour with regard to the origin of the barbels in Teleosts as seen from the fate of the cement organs in *Acipenser* As against this view Kerr (1919) is of opinion that during ontogeny certain phases in the development of the organs have been slurred over or even omitted giving rise to a condition in Dipnoi and Anura where the organs were known to take their origin from the ectoderm.

But instances, wherein different or intermediate conditions in origin within the same group, which would have gone in favour of this theory, are lacking Still the fact that in Teleostei and Dipnoi, the two intermediate groups of vertebrates possessing cement organs, they are known to originate from the *inner* layer of ectoderm whereas in the more highly evolved Anura the secretory cells of the glands are derived from the *superficial* layer of ectoderm, cannot be without some phylogenetic significance However, more work on the cement glands in fishes, especially of Teleosts, is required before this and allied questions can be solved in a satisfactory way

Summary

1 There are three pairs of cement glands in *Etroplus maculatus* situated on the dorsal side of the head, the anterior-most pair being smaller than the posterior two pairs

2 They produce mucus which help to attach the larva to the bottom till it is capable of independent swimming movement

3 The gland rudiments first appear when the embryo is thirty-eight hours old as thickenings of the inner layer of the ectoderm

4 The gland cells soon enclose a cavity into which the secretion is poured and by the time of hatching the outer layer of ectoderm over the cavity is lost

5 The glands grow in size and remain active till the fourth day after which they begin to degenerate They shrink in size, get flattened out and the superficial layer of ectoderm grows over them They disappear by the seventh day

Acknowledgment

I wish to thank Professor R Gopala Aiyar, Director, University Zoological Research Laboratory, Madras, for his constant help and valuable suggestions during the course of this work My thanks are also due to the University of Madras for awarding me a Research Studentship

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REPORT ON SOME NEMATODE PARASITES OF KABUL, WITH DESCRIPTIONS OF NEW SPECIES.

By S A Akhtar

(From the Department of Biology, Faculty of Medicine, Kabul)

Received October 18, 1937
(Communicated by Dr M. B Mirza, D sc)

The present paper deals with some Nematode parasites of different animals of this place, which the writer has come across during the last few months One new species of the genus *Ascaridia* Dujardin, 1845, one of the genus *Subulura* Molin, 1860, and one of the genus *Tachygonetria* Wedl, 1862, have also been described in it

The writer expresses his grateful thanks to Dr M B Mirza, Director, Zoological Laboratories, Muslim University, Aligarh, for kindly going through the manuscript Sincere thanks are also due to Dr B Prashad, Director, Zoological Survey of India, for facilities in consulting literature and examining certain specimens in the collection of the Indian Museum at Calcutta

1 *Ascaris lumbricoides* Linnaeus, 1758

Only one male specimen of this species, 248 mm long and about 3 mm thick, was obtained from a man

2 *Ascaridia razia* n sp *

A pair of the worms of genus *Ascaridia* Dujardin (1845) was recovered from the intestine of a wild pigeon (*Columba livia*)

Morphology —Body is white and cuticle with transverse striations Anterior end is with three large and well-defined lips, each bearing two cephalic papillæ Cervical alæ are present Oesophagus is club-shaped and is without a posterior bulb

Male —Transverse striations over the body are 0 015 mm apart There is a pre-anal sucker and a few rounded or oval bodies are found in front of the sucker within the body cavity There are oblique muscles near the sucker, all terminating in the centre of the sucker Caudal alæ are small and narrow beginning in front of the posterior end of the body and reaching up to the level of the pre-anal sucker

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* The species is named after the writer's daughter Razia Khatoon.

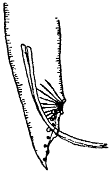

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FIG 1. *Ascaridia razia* Posterior extremity of male, laterally

There are only nine pairs of big caudal papillæ, four pairs of which are pre-anal, one adanal, and four pairs are post-anal Spicules are two, subequal and alate There is no gubernaculum Tail ends in a conical spine and is slightly incurved

Measurements —

Length of the worm	20 812 mm
Maximum thickness	0 787 ,,
Length of lips	0 045 ,,
Diameter of head	0·146 ,,
Length of œsophagus	1·575 ,,
Diameter of pre-anal sucker (lengthwise)	0·135 ,,
Distance between pre-anal sucker and cloaca	0·200 ,,
Length of spicules	1·732 and 1·687 ,,
Length of tail	0 450 ,,

Female —Transverse striations over the body are 0 022 mm apart Vulva is a little behind the middle of the body Tail is slightly truncate at the level of the cloaca ventrally and then compressed dorso-ventrally ending in a blunt point

Measurements —

Length of the worm	32 075 mm
Maximum thickness	1 132 ,,
Length of cervical alæ	2 700 ,,
Length of œsophagus	2 002 ,,
Distance between vulva and posterior end	15·480 ,,
Length of tail	0·825 ,,
Size of egg	0·180 × 0·157 ,,

Ascardia razia differs from all its allied species in different measurements. It also differs from *A columbæ* (Gmelin, 1790) Travassos, 1913, in the diameter of head, distance of body striations, lengths of tails, diameter of pre-anal sucker and in the distance between the pre-anal sucker and the cloacal aperture The new species *A razia* resembles *A stroma* (v Linstow, 1899) Railliet and Henry, 1914, in having comparatively small number of big caudal papillæ, but differs much from it in the length of œsophagus (about 1/13 of the length of the body) which is longer, the length of the tail in male (1/46 of the body length) which is shorter, and in the length of the tail of female (1/38 of the body length) which is longer Oblique muscles of the sucker are strong and they terminate together in the centre of the sucker There are only nine pairs of caudal papillæ, four pairs of which are pre-anal, one pair adanal (biggest of all the papillæ) and four pairs are post-anal Moreover the eggs of *A razia* are larger than those of all the other species of *Ascaridia*, also larger than the eggs of *A stroma*, whose eggs are exceptionally large in the genus All these are salient characters to differentiate *A razia* from all other species of the genus

3 *Subulura kabulanus* n sp

Five specimens (3 males and 2 females) of the genus *Subulura* Molin, 1860, were recovered from the intestine of an orange-billed pheasant (*Tetraogallus* sp)

Morphology —The body is yellowish white, cuticle striated coarsely and the anterior portion of the body is curved in both the sexes Anterior end of the body is blunt and lateral alæ are present The buccal capsule is with chitinous walls and has three teeth at its depth one being dorsal and two sub-ventral There is a pharynx at the anterior portion of œsophagus

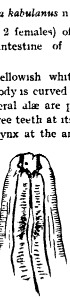

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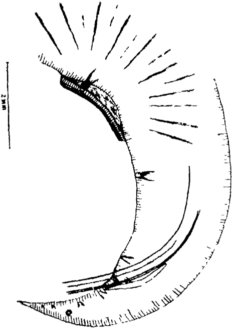
FIG. 2. *Subulura kabulanus*. Anterior extremity, laterally.



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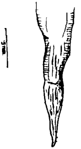

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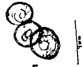

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Fig 3 *Subulura kabulanus* Posterior extremity of male, laterally
Fig 4 „ „ „ „ female, laterally
Fig. 5 „ „ Eggs

which is somewhat thicker Oesophagus is club-shaped, jointed to a posterior bulb by a narrow portion The bulb is subglobular

Male—The posterior portion of the male is curved and is with a terminal spine Small caudal alæ as well as pre-anal sucker are present The sucker is with a chitinous rim surrounded by strong oblique muscles The interior of sucker is somewhat deep and its surface is with fine longitudinal striations The spicules are equal, curved, alate and fine-pointed Gubernaculum is long and there are ten pairs of caudal papillæ, three of which are pre-anal, two adanal and five pairs are post-anal

Measurements —

Length of the worm	11 587	mm	9 593	mm
Maximum thickness	0 458	,,	0 450	,,
Diameter of head	0 090	,,	0 067	,,
Length of buccal capsule	0 058	,,		
Width of buccal capsule at post end	0 031	,,		
Height of teeth	0 018	,,		
Length of œsophagus with bulb	1 192	,,	1 170	,,
Diameter of pre-bulbular swelling of œsophagus	0 135	,,	0 090	,,
Length of the bulb	0 225	,,	0 205	,,
Diameter of the bulb	0 225	,,	0 215	,,
Length of pre-anal sucker	0 210	,,	0 202	,,
Distance between pre-anal sucker and cloacal aperture	0 450	,,	0 212	,,
Length of spicules	1 350	,,	1 408	,,
Width of spicule	0 036	,,		
Length of gubernaculum	0 135	,,		
Length of tail	0 256	,,	0 283	,,

Female—The tail of female is compressed dorso-ventrally and is bluntly spear-shaped Vulva is a little in front of middle of the body at about 4/5 of the length Eggs are with fully-formed embryo and sub-globular

Measurements —

Length of the worm	16 583	mm	19 467	mm
Length of buccal capsule	0 063	,,		
Width of buccal capsule at post end	0 036	,,		
Height of teeth	0 015	,,		
Length of œsophagus with bulb	1 237	,,	1 609	,,
Width of pre-bulbular swelling of œsophagus	0 202	,,		
Length of the bulb	0 225	,,		
Distance of vulva from anterior end	7 448	,,	8 212	,,
Length of tail	1 193	,,	1 450	,,
Width of caudal spear-shaped portion	0 225	,,		

Size of eggs .. 0 063 – 0 072 × 0 045 – 0·058 mm.

Subulura kabulanus, discovered by the writer, differs from all other species of the genus in its measurements and structure Through the kindness of Dr B Prashad, the writer could examine two or three species of *Subulura*, particularly *S galloperdicis* Baylis and Daubney, 1922, in which oblique muscles are not so strong and the margin of the sucker is not well-defined *S kabulanus* appears to resemble, to some extent in its general form and structure as well as in the number of caudal papillæ, *S andersoni* (Cobbold, 1876) Railliet and Henry, 1914, but differs markedly from it in its measurements, showing its spicules to be longer, gubernaculum smaller, sucker longer, œsophagus smaller and the distance between the pre-anal sucker and cloacal apperture being less than in the named species Above all, *S kabulanus* possesses a chitinous rim of the sucker of quite peculiar shape, appearing to be made up of upright bars placed side by side These characters are sufficient to differentiate it from all other allied species and in this connection it is suggested that the presence or absence of chitinous rim of pre-anal sucker be added to the generic characters of *Subulura*

4 *Tachygonetria microstoma* Drasche, 1884

Two male specimens of this species were obtained from the cæcum of a tortoise (*Testudo* sp) The specimens were, however, found to differ from the published account of the species in the following respect —

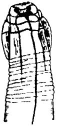
Maximum thickness .	0 240 mm
Length of spicule .	0 102 ,,
Length of tail ..	0 220 ,,

5 *Tachygonetria inflatocervix* n sp

Worms of the genus *Tachygonetria* Wedl, 1862, were recovered from the cæcum of a tortoise (*Testudo ibera*)

Morphology —Small worms, mouth surrounded by six inconspicuous lips and head bearing four big cephalic papillæ Cervical cuticle is inflated symmetrically, forming a projecting cuticular collar, covering four or five annulæ in the middle of the collar Cuticle of the body is coarsely striated, sometimes except on the dorsal surface and the tail, where the striations are fine Vestibule is short and without any chitinous armature Oesophagus is cylindrical and long with a posterior bulb containing a valvular apparatus Excretory aperture is behind the bulb Intestine is simple and without diverticulum Lateral flanges are absent.

Male —The body is obliquely truncate ventrally at the level of the cloaca There is only one spicule and that is acicular Gubernaculum present Tail or the posterior portion of the body is coiled and is with narrow alæ.



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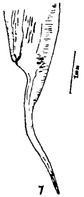

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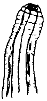

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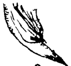

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Fig 6 *Tachygonetria inflatocervix* Anterior extremity
Fig 7 " " Posterior extremity of female, laterally
Fig 8. " " " " male laterally
Fig 9 " " Anterior extremity of male

Tail is conical and fine-pointed, bearing three pairs of pericloacal papillæ—one pair of pre-anal, one pair latero-ventral and one pair of adanal papillæ In addition to these there is a pair of voluminous papillæ on the middle of the tail

Measurements —

Length of the worm .. .	2 844	mm
Maximum thickness .	0 187	,,
Diameter of mouth ..	0 225	,,
Length of vestibule . ..	0·009	,,
Diameter of cervical collar	0 033	,,
Length of œsophagus with bulb .	0 603	,,
Length of spicule .. .	0·117	,,
Length of gubernaculum	0 031	,,
Length of tail	0·072	,,

Female.—Cervical collar is well-developed and fully-distended covering up to twelve annulæ, often another collar develops behind the former. Vulva is behind the middle of the body and the tail is conical, long and tapering to a point. Uteri are two, eggs large, numerous and ellipsoidal and are segmented at deposition.

Measurements.—

Length of worm	2·970 mm	4·905 mm
Thickness	0·250 ,,	0·382 ,,
Diameter of mouth	0·040 ,,	
Diameter of collar	0·119 ,,	0·202 ,,
Length of vestibule	0·027 ,,	
Nervous ring behind the mouth	0·234 ,,	
Length of œsophagus with bulb	0·900 ,,	1·170 mm
Vulva from posterior end	1·427 ,,	2·430 ,,
Length of tail	0·346 ,,	0·517 ,,
Size of eggs	0·076 – 0·184 ×	0·081 – 0·090 ,,

Tachygonetria inflatocervix, discovered by the writer, differs from all species of *Tachygonetria* in its measurements, it also differs in the shape of its head. Cervical collar, which is not well developed in males, is fully distended in females and is often followed by another collar of the same type. It only resembles *T. microstoma* (Drasche, 1884) and *T. uncinata* (Drasche, 1884), in having a conical tail, bearing a pair of voluminous papillæ, but differs markedly from them in the shape and size of tail, particularly in female and also in the position of the last pair of voluminous papillæ, which is situated on the middle of the tail of male, instead of on the posterior third. These characters are sufficient to create a new species and in this connection it is suggested that "a pair of voluminous papillæ on the middle or posterior third of the tail" be added to the generic characters of *Tachygonetria*.

6. *Chabertia ovina* Railliet and Henry, 1909

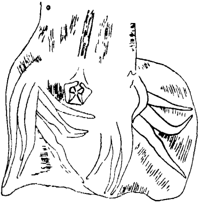
Five specimens of this species were obtained from the intestine of a sheep.

7. *Ostertagia marshalli* Ransom, 1907

Many specimens were obtained from abomasum of a sheep.

8. *Ostertagia tricuspis* Marotel, 1910

The species was originally described by Marotel in 1910, from Lyons in France. After that probably the species has not been reported, as yet, from any part of the world. It is interesting to record its occurrence for the first time in Asia After dissecting a large number of intestines of sheep, many worms of this species were recovered from one case only These worms are yellowish brown in colour and the cuticle is finely striated transversely There are twenty-four longitudinal ridges over the body The cuticle of the anterior end is dilated and the buccal cavity is very small



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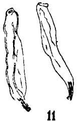

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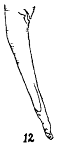

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Fig 10 *Ostertagia tricuspis* Posterior extremity of male, showing telamon
Fig 11 " " Spicules
Fig 12 " " Posterior extremity of female, laterally

Male—The pre-bursal papillæ are present and there is no accessory piece The spicules are equal and are divided into three in the posterior fifth of their lengths The median process is blunt at the tip while others are pointed There is a pentagonal structure (telamon) at cloaca.

Measurements —

Length of the worm	10·249 mm
Diameter of head	0·018 ,,
Length of œsophagus	0·819 ,,
Length of spicules	0·252 ,,

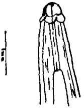
Female —Vulva is situated at about posterior fifth of the body and is with a flap on the anterior margin. Tail is digitiform with fine transverse lines a little in front of the tip. Five small papillæ-like dots appear to be on the tip of the tail.

Measurements —

Length of the worm	15·390 mm
Diameter of head	0·922 ,,
Length of œsophagus	0·922 ,,
Vulva from posterior end	3·240 ,,
Length of flap	0·285 ,,
Length of tail	0·315 ,,
Size of eggs	0·166 × 0·076 ,,

9 *Parabronema* sp

Only one female of this parasite was found in the beginning of the small intestine of a sheep. The anterior extremity is provided with dorsal and



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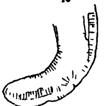

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Fig. 13. ***Parabronema* sp. Anterior extremity.**
Fig. 14. ,, Posterior extremity

ventral cuticular shields and is ornamented with six horse shoe-shaped cordons, lateral flanges are absent The buccal capsule is long and its posterior portion is cylindrical without annular or spiral thickenings and the œsophagus is also without any swelling The tail is short, bluntly conical and dorsally curved Anterior part of the body is reddish brown and the remaining portion yellowish brown Excretory aperture is near the beginning of the œsophagus, and the vulva is behind the œsophagus

Measurements —

Length of the worm	25 437	mm
Length of buccal capsule	0 175	,,
Length of œsophagus	2 340	,,
Distance of excretory pore from anterior end	0 220	,,
Distance of vulva from anterior end	7 200	,,
Distance of vulva from posterior end of œsophagus .	4 685	,,
Length of tail	0 180	,,

From the above description the specimen appears to belong to the species ***Parabronema skrjabini*** Rasovska, 1924, but as it differs from ***P skrjabini*** in the position of its vulva and as the male is wanting its correct specific determination is hardly possible

10 *Polymorphus boschadis* Schrank, 1788

Two specimens of this species were found in the intestine of a wild duck (***Anas*** sp)

Type-specimens of the new species as well as of certain others have been deposited in the Museum of the Zoological Laboratories, Muslim University, Aligarh, ***Ascaridia razia*** under No 935, ***Subulura kabulanus*** under No 936, and ***Tachygonetria inflatocervix*** under No 937

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STUDIES ON THE TREMATODE PARASITES OF BIRDS.

Part II. Morphology and Systematic Position of Some New Blood-Flukes of the Family Schistosomidae.

BY MAKUND BEHARI LAL, D Sc

(From the Department of Zoology, the University, Lucknow, India)

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[Communicated by Dr G S Thapar, M Sc , Ph D (London)]

THE discovery of the first genus of this family was originally made by Bilharz in 1851 when he recovered some worms from the mesenteric veins of a native of Cairo This was reported by Bilharz in 1852 who named it *Distomum hæmatobium* Later this genus was reported by other workers under different names, *viz* , *Gynæcophorus* Diesing, 1858 , *Bilharzia* Cobbold, 1859 , *Thecosome* Moquin-Tandon, 1860 The name "Distomum" for this blood-fluke was a misnomer and was replaced by *Schistosoma* by Weinland in 1858 , and although later workers tried to immortalize the name of Bilharz, the discoverer of this blood-fluke, by naming it after him, the name had to be given up in view of priority of *Schistosoma*

Looss (1899) created the family Schistosomidæ for the genus *Schistosoma* Weinland (1858) and added the second genus *Bilharziella* to the family which was described earlier by Kowalewski (1895) under the name of *Bilharzia polonica* Odhner (1910) described *Gigantobilharzia* and later (1912) added another genus *Ornithobilharzia* Johnston (1917) reported the genus *Austrobilharzia* from Australia Three years later Skrjabin and Zakharow (1920) removed an earlier form *Bilharziella pulverulenta* Braun, 1901, to their new genus *Dendritobilharzia* In the same year they recorded another new genus *Trichobilharzia* Tanabe (1923) created the genus *Schistosomatium* for his experimentally obtained forms in white rats and mice Travassos (1923) added the genus *Macrobilharzia* to the family The latest work on the family is that of Price (1929) where he recognizes all these forms, except *Macrobilharzia* of Travassos which he regards as a synonym of *Ornithobilharzia*, and creates three new genera *Microbilharzia*, *Heterobilharzia* and *Paraschistosomatium* He also divides the family Schistosomidæ into two subfamilies, Schistosominæ and Bilharziellinæ Subsequently (1931) the same author in a brief note revives the genus *Macrobilharzia* and suppresses one of his newly created genera, *viz*, *Paraschistosomatium* as a synonym of *Macrobilharzia* The family Schistosomidæ is of recent occurrence in India Montgomery (1906) described *Schistosoma indica*, from mammals Christophers and Stephens (1905) discovered an egg of *Schistosoma spindalis* in the urine of a Madrasi The larval stages have been recorded by Soparkar (1921) and Sewell (1922) Leiper (1923) mentions that several cases of infection occurred in the neighbourhood of Hyderabad after the return of infected troops from Egypt

From birds, however, the family has been very recently reported in India The earliest case, so far as the writer is aware, is from Rangoon when Gogate (1934) obtained two immature male specimens of blood-flukes from wild ducks Although he has neither given diagrams nor adequate description of his forms, he tentatively refers them as *Ornithobilharzia* sp under the subfamily Schistosominæ The writer, in the course of his investigations, has also come across two cases of blood-fluke infection in birds These forms, which are being described in the present communication, come under the subfamily Bilharziellinæ Price, 1929, but owing to certain peculiar characters presented by them necessitate the emendment of the subfamily diagnosis

Subfamily Bilharziellinæ Price, 1929, *emended*

Schistosomidæ Suckers present or absent Gynæcophoric canal absent or imperfectly formed or sometimes well developed Paired intestinal cæca short, uniting cephalad of the middle of the body, common cæcum long, with or without lateral dendritic branches Testes numerous and situated behind the cæcal union along the course of the common cæcum Uterus short, containing a single egg

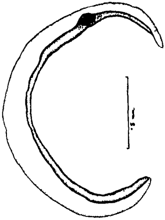
Type genus—*Bilharziella* Looss, 1899

Chinhuta indica N G N Sp

A very large number, exceeding 200, of specimens of this species were obtained from the main blood vessels and internal organs of the common teal, *Nettion crecca* The bird which was captured at the Chinhut Lake, about 8 miles from Lucknow, was kept under observation but died next morning The post-mortem examination revealed a very heavy infection with *Chinhuta* There were signs of lesion formation in liver, kidney and even lungs

The animals were inactive showing little movement when liberated in salt solution They appeared white in colour and were sticking fast to the tissues by their powerful ventral sucker which is a cup-shaped structure with slightly pedunculated base

Male—It is a long, thin animal with blunt anterior end and tapering posterior end The length of the specimen is 2 95 mm and the maximum breadth which is a little behind the cæcal union is ·375 mm The lateral edges of the body are rolled inwards to form a deep gynæcophoric groove which extends right from the hinder end of the oral sucker up to the posterior end



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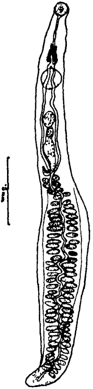
TEXT FIG 1 *Chinhuta indica* male—Lateral view showing the Gynæcophoric groove.

The circular oral sucker lies ventrally and is rather weakly developed It measures ·1 mm in diameter The ventral sucker, which is muscular and very powerful, is larger than the oral sucker and measures 15 mm in diameter and lies at a distance of 5 mm from the anterior end

The mouth leads into a long thin œsophagus which measures ·375 mm There is no pharynx in these forms There are a large number of unicellular glands surrounding the base of the œsophagus and they appear to be arranged in a grape-bunch manner It is rather difficult to surmise the exact nature of these glands but probably they may be producing some secretions which prevent the clotting of blood on which these parasites feed

The œsophagus divides into two intestinal cæca at its posterior end just in front of the ventral sucker There is a small cæcal projection directed forwards just at the intestinal bifurcation which probably is a representative of the H-shaped cæcal bifurcation seen in some other blood-flukes. The two intestinal cæca run dorsal to the ventral sucker and after a brief course join together in the pre-equatorial region to form a common cæcum at a distance of ·625 mm behind the ventral sucker and 1 275 mm from the anterior end The common cæcum which is longer than the separate intestinal cæca runs behind in a zigzag manner ending blindly at a distance of about 1 mm from the posterior end The common cæcum shows thickenings of its walls at various places which also become sharply pointed



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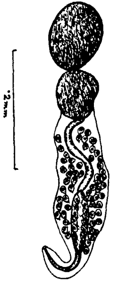

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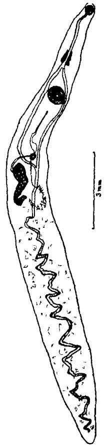
Text Fig 2. *Chinhuta indica* male—Ventral view showing general anatomy

Text Fig. 3. Cirrus sac showing bilobed vesicula seminalis, prostate cells and pars prostatica—ventral view

The testes, which vary between 70–80 in number, lie on the two sides of the common cæcum, beginning just behind the cæcal union and ending a little in front of the cæcal end They are oval bodies of variable size, the largest measuring ·125 mm × 04 mm and the smallest measuring 05 mm × 025 mm The vesicula seminalis is a lobed structure, situated behind the ventral sucker It consists of a large oval lobe measuring 117 mm × 0875 mm and a small lobe, irregular in shape measuring 087 mm × 07 mm and joined by a very narrow constriction in the middle The smaller lobe of the vesicula seminalis is enclosed within the cirrus sac which is a long cylindrical body containing the ejaculatory duct, pars prostatica and a large number of prostate gland-cells The terminal end of the cirrus sac is bent and opens at the genital pore on the left side of the median line just in front of the level of the cæcal union A small S shaped duct leads from the vesicula seminalis to open into an elliptical pars prostatica measuring 1 mm in length A small duct terminating in the cirrus arises from the pars prostatica, takes a bent course and opens out at the genital pore



Chinhuta indica female—ventral view showing general anatomy.

Female.—The female is much smaller in size than the male It measures 1 8 mm in length and has a maximum breadth of about 19 mm behind the ovary in the level of the vitellaria The body is flat and narrower towards the two ends It does not show any inrolling of its lateral edges The oral sucker is ventral and measures 04 mm in diameter The ventral sucker is strongly developed as in the case of the male and measures 075 mm in diameter

The mouth leads into a long œsophagus which measures ·225 mm and is surrounded at its base by the unicellular œsophageal glands It bifurcates into the two intestinal cæca at its posterior end, about 075 mm in front of the ventral sucker The two intestinal cæca run for a short distance and unite to form a common cæcum at the level of the anterior end of the ovary at a distance of ·25 mm from the ventral sucker and about ·675 mm from the anterior end The common cæcum follows a zigzag course behind, shows peculiar thickenings of its wall and ends at a distance of ·05 mm from the posterior end

The ovary is an elongated sinuous body, broader anteriorly and tapering posteriorly It lies at a distance of 27 mm behind the ventral sucker and measures ·155 mm in length and ·05 mm in maximum breadth The oviduct arises from the right side of the broad anterior end of the ovary and after a sharp curve enters the ootype The ootype is surrounded by small unicellular shell-glands The short straight uterus arises as a broad tube in front of the öotype and ends at the genital pore, 04 mm behind the ventral sucker No eggs were found in the uterus

The vitellaria consist of distinct and large follicles which extend right behind the ovary to the posterior end They lie on the two sides of the common cæcum and pour their yolk by narrow ducts into a large U-shaped vitelline reservoir which lies at the level of the ovary and leads by a thin duct to open into the öotype

To sum up, the genus *Chinhuta* is characterised thus —

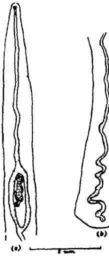
Male with a well-developed gynæcophoric canal, extending from a little behind the oral sucker up to the posterior end, female with flattened body and smaller than the male Suckers present Oesophagus provided with unicellular œsophageal glands The two intestinal cæca unite a little in front of the middle of body, common cæcum long, without lateral branches but provided with angular thickenings of its wall Testes vary between 70–80 in number and extend from the cæcal union to the posterior end of the animal Cirrus pouch well developed, enclosing a part of vesicula seminalis, prostate gland-cells, pars prostatica and the cirrus The terminal end of the cirrus sac is slighlty bent to the left side The male genital pore lies slightly to the left of the median line near the middle of the body The ovary is elongated and sinuous, situated at the level of the cæcal union Uterus short and straight The female genital opening is a little behind the acetabulum Vitellaria situated on the sides of the common cæcum, in distinct follicles A vitelline reservoir is present

Type species—*Chinhuta indica*

Remarks—The new genus differs from the members of the subfamily Bilharziellinæ in having an extremely well-developed gynæcophoric canal in which feature it stands near the subfamily Schistosominæ But it differs from the subfamily Schistosominæ in having cephalad union of the intestinal cæca and testes behind the cæcal union, features in which it closely resembles the subfamily Bilharziellinæ The genus, in fact, forms a connecting link between the two subfamilies. The nearest ally of the new genus is the genus *Bilharziella* with which it shows several features of resemblance It differs, however, from the genus *Bilharziella* in having an extremely well-developed gynæcophoric canal, in the possession of the œsophageal glands, bent terminal end of the cirrus sac and in the position of the female genital opening It is, therefore, considered necessary to create a new genus which is designated *Chinhuta* owing to its recovery from a bird caught at the lake, Chinhut

Gigantobilharzia egreta N Sp

Only one male specimen of this parasite was obtained from the renal vein of the cattle egret, *Bulbulcus ibis coromandus* The worm was quite inactive and white in colour when liberated in normal salt solution It is a long thread-like, thin worm and is somewhat fragile The length



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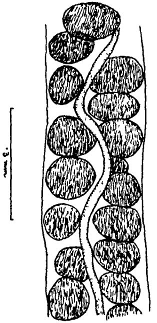

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TEXT FIG 5. *Gigantobilharzia egreta* male—Ventral view of (*a*) Anterior end showing intestine and cirrus sac and (*b*) Posterior end showing the termination of intestinal cæcum

TEXT FIG. 6. *G. egreta*, middle of the body showing the relation of testes with intestine of the specimen, obtained by the writer, is 38·85 mm of which about 35·6 mm is occupied by the testes. It is broadest in the middle where it measures ·275 mm. The body tapers gradually towards the anterior end, posteriorly also it tapers but widens again to end in a dilated and blunt posterior end. There is no trace of an oral or a ventral sucker. The gynæcophoric canal is also absent. The mouth begins in a shallow depression and is continued behind into a long œsophagus 1·2 mm in size. The intestinal cæca arise from the posterior end of the œsophagus and run for a very short distance to meet to form the common intestinal cæcum. The cæcal union takes place at a distance of about ·4 mm behind the cæcal bifurcation. The common cæcum extends in a zigzag manner to almost up to the dilated posterior end of the animal.

The exceedingly large number of testes, more than 600, are round or oval bodies and lie on the two sides of the common cæcum. They vary in size, the largest measures ·15 mm × ·1 mm and the smallest ·075 mm × ·05 mm. The vesicula seminalis lies in the space enclosed by the bifurcation and re-union of intestinal cæca. It is a sinuous structure, about ·2 mm in size and ends in a small papilla on which is situated the genital aperture which lies at a distance of ·175 mm from the cæcal union and ·225 mm from the cæcal bifurcation. The writer has not been able to observe clearly a cirrus sac in this species which probably is present.

Remarks.—So far only two species of the genus have been described, *G. acotylea* by Odhner (1910) from Sweden and *G. monacotylea* by Szidat (1930) from East Prussia. The present form, of which the writer has obtained a male specimen, differs from both the existing species in several important characters. It differs from *G. acotylea* in the absence of a gynæcophoric canal, in having its genital opening slightly dextral and in possessing a comparatively much longer œsophagus. From *G. monacotylea*, it differs in the absence of an oral sucker, in the position of the genital pore, in much smaller vesicula seminalis and in having a much longer œsophagus. It is therefore, designated as a new species for which the name *Gigantobilharzia egreta* is proposed.

Remarks on the Family Schistosomidæ

The family Schistosomidæ contains 11 genera and these have been grouped into two subfamilies by Price (1929). The subfamily Schistosominæ is distinguished from the other subfamily Bilharziellinæ on the basis of a well-developed gynæcophoric canal and re-union of the intestinal cæca behind the middle of the body. The discovery of the new genus ***Chinhuta***, with an extremely well-developed gynæcophoric canal and cephalad union of the intestinal cæca, is very interesting as it appears to form a connecting link between the two existing subfamilies The difference between these subfamilies, therefore, narrows down to only one character, *viz*, the level of the re-union of the intestinal cæca This naturally creates a doubt as to the validity of the subfamily division under the family

Another interesting feature of systematic value is the occurrence of the cirrus sac which has been described in some species of the family Unfortunately, the writer could not have an access to all the literature on the subject but feels that a re-study of some of the forms is needed Species have been described under the same genus in which a cirrus sac is either present or absent It is rather strange to find this discount on the value of the cirrus sac, which has been regarded as a subfamily character in various cases The writer, therefore, urges for a revision of the genera and species of the family Schistosomidæ in order to remove the prevailing confusion and thereby to place the group on a sound basis

The writer wishes to record here his sincere thanks to Dr G S Thapar for his valuable criticism and suggestions during the course of this work

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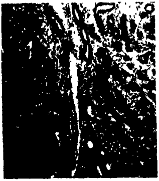

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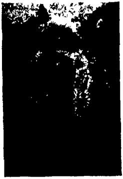

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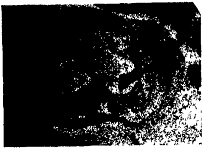

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Fig. A -- Section of Liver of *Nettion crecca* showing lesion formation due to the presence of *Chinhuta indica*

Fig B — Section of Kidney of *Nettion crecca* showing *Chinhuta indica* in the cavity of the kidney

Fig C.—Section of Kidney of *Nettion crecca* showing *Chinhuta indica* in the renal vein, obliterating the cavity

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THE BRACKISH-WATER FAUNA OF MADRAS.

BY N. KESAVA PANIKKAR, M.A., D.Sc.,

AND

R. GOPALA AIYAR, M.A., M.Sc.

(From the University Zoological Research Laboratory, Madras.)

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Introduction

THE study of the brackish-water fauna of India dates from the time of Stoliczka, and ever since he published his interesting paper in 1869, numerous isolated accounts of the fauna of the Gangetic Delta, dealing with particular groups or species of animals, have appeared from time to time. Faunistic and ecological studies pertaining to definite brackish-water regions were not, however, made until Annandale commenced, in 1907, his series of contributions on the fauna of the brackish ponds of Port Canning in Lower Bengal. This was followed by the biological survey of the Chilka Lake, under the leadership of Annandale and Kemp (1915). The various groups of animals collected from this lake were worked out by specialists in different parts of the world, these reports (1915–1922) have formed an excellent ground-work for further studies on Indian brackish-water fauna. The results of similar surveys of Taléh Sap in Siam, Tai Hu in China, and

Lake Biwa in Japan, were published in the succeeding years, in Annandale's *Zoological Results of a Tour in the Far East* (1916–1925) In recent years, considerable data have accumulated on the euryhaline fauna of the Gangetic delta mainly by the contributions of Annandale, Kemp, Sewell, and other officers of the Zoological Survey of India An investigation of the brackish-water areas near the city of Madras was thought desirable as no attempt has been made to advance our knowledge of the brackish-water animals of South India beyond the references in the Chilka Lake reports. Apart from this aspect, the local animals which could be examined first-hand are so little known in many of the educational centres in India that both the student and the teacher are often handicapped owing to the paucity of familiar local species illustrating several biological phenomena , hence this work was planned with the hope that it may benefit College students in general Comparatively little is known of the bionomics of the brackish-water types of animals, and since the place chosen was suited for close and constant investigation, an intensive ecological study was made extending over a period of three years As will be seen from the following account, a fairly rich and specialized fauna exists at Adyar, showing interesting peculiarities both in mode of life and life-history

Material and Methods

The account of the fauna given here is based upon a number of collections from the Adyar backwater, Adyar River, and the brackish-water localities of the Cooum, made within the course of three years, dating from November 1933 A few collections made previous to this have also been utilized, but these do not include any species that we have not taken subsequently During the early part of the survey, *i e*, for about a year, the Adyar backwater and the river were visited about thrice a month on an average, and regular shore and plankton collections were made The backwater and the river were less frequently visited during the next year, but special attention was devoted to the upper reaches of the river and the pools of brackish-water near the Boat Club Observations were also made on the fauna of the small islands in the river near the Elphinstone Bridge, and the brackish tracts of the Cooum Field observations during the third year have confirmed the previous years' results

The shallow nature of the backwater and the river was of considerable advantage in that no elaborate equipment was necessary for conducting this study Shore collections were made by us regularly during our visits For examining the fauna of the mud, the most useful instrument was a large shovel with which mud could be levered up without causing much disturbance to the organisms Mud taken in this manner from the backwater, salt pools, river, etc, was carefully examined in the laboratory and the organisms picked up The tow-net was used to collect the free-swimming invertebrates, small fish and larvæ The collection also includes specimens obtained by dredging from the deeper parts of the river

For the collection of fish, prawns and the larger species of swimming crabs, we have entirely depended upon the implements used by the fishermen of the locality These were closely meshed nets of various sizes and shapes Fishing is usually done in the mornings Catches obtained by the fishermen from the river and the backwater were regularly purchased until representatives of most of the species were obtained Afterwards, their catches were only examined on the field

The hydrographical readings given were kindly taken by Dr M K. Subramaniam, based on analyses of water-samples from the Adyar River near the bar We have taken a number of temperature records on subsequent occasions, which have clearly illustrated the wide range of variation that is likely to occur from place to place, and also the extent of diurnal variations

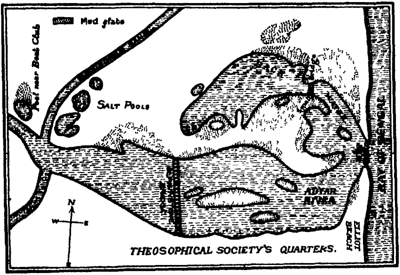
The species have been worked out by us, and in many cases the identifications have been checked with the help of the collections of the Madras Government Museum Dr S L Hora has kindly identified for us four species of Gobies, Dr H S Rao, three Gastropods, and Dr F H Gravely, one spider We wish to thank all of them for their valuable help

Description of the Area

The brackish-waters of the city of Madras (Lat 13·4', Long 80·17' E) include the backwater at Adyar, and the mouth of the Adyar River which is in close association with the former To this may be added those portions of the Cooum River and the Buckingham Canal, which are either in communication with the sea or with the Adyar backwater or river The present study is mainly based on animals collected from the backwater and the river-mouth where the fauna is fairly rich and characteristic A number of collections have also been made from the bar where the River Cooum opens into the sea This account is also applicable to the other brackish-water regions of the Cooum and the Buckingham Canal as the macroscopic fauna of these localities consists only of a few of the resistant species that are observed at Adyar

The Chingleput or the Adyar River opens into the sea five miles south of Fort St George The northern side of the river leads into the backwater which is a shallow sheet of water about one square mile in area, lying between

San Thome and Adyar. On the east, the backwater closely borders the sand bank that separates it from the seashore, while its northern and western portions extend into shallow mud-flats, which are covered by water only during high tide, and are more or less permanently dry during the hot months of the year, March to July There is no sharp separation between the backwater and the river-mouth proper as the former is something like a bay on the northern bank of the river, from the faunistic point of view, the portion of the river from the Elphinstone Bridge up to the bar, nearly a mile in length and about quarter to half a mile in width, along with the backwater forms a typical brackish-water zone As the river is very shallow lower down the bridge, a few island formations occur in the middle of its course



TEXT-FIG 1

The peculiarity of the place is brought about by the fact that the Adyar River is not in communication with the sea throughout the year As the source of the water-supply for the river is the comparatively low rainfall of the Chingleput District (about 49 inches per annum), it is full only during the North-East Monsoon period (October to December) when there is good flow of fresh water into the sea, and the river-mouth is fairly deep and broad during the flood season This condition exists only for a period of about two months. As the strength of the current gradually weakens, tidal effects are markedly felt and the rapid flow of water is very much inhibited The presence of the backwater is of much significance in that it allows a good admixture of sea water and freshwater These conditions change with the advent of summer The river becomes gradually reduced to a languid line of water with practically no flow By about the end of January, the fringes of the backwater get dried up, leaving some of the mud-flats exposed The immediate effect is an increased flow of water from the sea into the river and the backwater, but this is soon retarded by the action of breakers, which raise up a sand bank at the mouth of the river on a line with the shore Thus the connection of the river and the backwater with the sea is intermittent during February, but it is completely cut off by the end of March The sand bank, or the *bar* as it is called, widens out in latter months, reaching a maximum width of about three-quarters of a furlong The bar is prominent until the next rainy season when the river-current is again strong enough to force its way into the sea The times of opening and closing of the bar may be considered as approximately occurring between October and November, and between February and April respectively

The *Cooum River* is only a tidal creek (similar to the Matla River of Lower Bengal) which has a tortuous course in the city of Madras It is practically dry during the summer months At the monsoon time, a good amount of rain water collects in the river A temporary connection is now established with the sea, about half a mile south of Fort St George, where the river crosses the Buckingham Canal Soon after the monsoon, however, a bar is raised, but this is quite low and allows the inflow of small quantities of sea-water during high tide The portion of the Buckingham Canal with which we are concerned in this paper is that between the Adyar and the Cooum, from the point where it cuts the former near the Adyar Boat Club four miles up the river, to the point where it crosses the Cooum near the Napier Bridge to the south of Fort St George

Geologically, the whole locality is built by the sea straggling over a large area of the sandy soil characteristic of the greater part of the Coromandel Coast The soil of the adjoining areas consists of a mixture of sand and red loam The nature of the soil is such that in the wet weather, many temporary pools of water are formed, this is enhanced by the presence of tidal creeks like the Cooum In the formation of the backwater, the sand-laden current of the coast coming from the south and grazing the shore in a northerly direction towards the head of the Bay of Bengal, must have played a prominent part since it has caused the sea to recede, and has directed the water and silt of the sluggish river in the direction of the backwater A number of marine and estuarine shells in a sub-fossil or fossil state have been recorded from the Adyar locality by Oldham (1893)

The bottom of the river as well as of the backwater is of a muddy consistency, but the sandy element in the soil becomes pronounced as we approach the sea Excepting on the eastern border, the whole of the backwater-edge is muddy, composed of thick brown mud mixed with black clay, the latter predominating in its northern sides where the bed is almost completely composed of fine, loose clay In the river-bed, the clay is less marked, but the soil is composed of sand and mud mixed in more or less equal proportions The boulders of the Elphinstone Bridge and the small bridge near the Adyar Cemetery, and the stony embankment near the Theosophical Society's Quarters on the southern bank of the river are the only hard substrata in this brackish-water tract, giving shelter to typical rock-dwelling species

The Depth —The chief difference between the river and the backwater lies in their respective depths Nowhere in the backwater is the maximum depth more than 4 feet during low tide, except during floods Two distinct zones may be observed in the backwater *a middle zone* that never dries up even in the hottest months and extends from the bar up to the small bridge in a curve , and *a marginal zone* on the fringes of the former, consisting of mud-flats, which are completely submerged only during monsoon times and are normally left exposed during low tide The relative depths of the two zones are such that when the marginal zone is just exposed, the water in the middle zone will be two to four feet deep In contrast with the backwater, the river is considerably deeper , even during the dry weather, a channel, nearly six feet deep, is noticeable near its southern bank up to about a mile from the sea This extends right up the river and is navigable for small country crafts A similar deep channel is seen on the northern bank almost up to the bridge but beyond this up to the Boat Club the river merges into a series of mud-flats and small pools of brackish-water These pools are brackish although many of them have no direct communication with the river Their brackish nature is the result of percolation of water through the raised banks One such pool near the Boat Club is fairly big and will be specially referred to later Higher up the river, the pools contain only fresh water and are inhabited mainly by freshwater organisms

The Tides —The tides are felt only in the months during which the bar is open , their influence is felt up to a distance of about three to four miles up the river The maximum tidal effect is a little after the monsoon, from about January to the end of February, when the river-current is feeble

The maximum tidal range is about three feet. As has been mentioned above, the initial drying up of the backwater during the early summer months is followed by an increased flow of water from the sea into the river and backwater until a bar is formed

The Vegetation—The vegetation is rather poor in the river as may be expected from the depth and the flow of water, but the backwater is in sharp contrast with this, its shallow stagnant situation being particularly suited to the luxuriant growth of algæ Numerous forms of algæ inhabit the middle zone of the backwater, chief among them are *Enteromorpha* and *Chætomorpha* Algal beds are best developed during the summer months of the year when they occur almost everywhere and give shelter to numerous organisms The bottom of the middle zone of the backwater and the shallow portions of the river is closely covered with *Potamogetons* while marsh plants like *Avicennia* and *Sueda* are quite common in the mud-flats and the islands in the river As we proceed higher up, freshwater forms like *Spirogyra*, *Ceratophyllum* and others may be found in large numbers

The Environment

The salinity, temperature, pH, chlorine and excess base values are given in the accompanying table, from a set of readings taken in 1933 These readings refer to the conditions near the bar As may be expected from the nature of the locality, the salinity of the water in the backwater and the river is liable to great variation, being not only different in different times of the year, but also varying in different places at the same time. The salinity is highest from January to March when the rains have practically ceased but the bar remains open—a period during which the maximum

TABLE I

Hydrographical Readings Averages for 1933
Adyar River Water, near Bar

		Bar open					Bar closed			
Nov	Dec.	Jan.	Feb	Mar	Apr	May	June	July	Aug.	Sept.
Temperature 26 6 .	25·4	25·0	26 2	27 7	28·2	29·6	28 8	28 5	28 5	28·2
pH	8 50	8 48	8·55	8 46	8 46	8 65	9 07	9 15	8 82	8·70
Excess Base .	30·15	20·73	23·20	17 59	25·16	24 90	24 52	25 5	23 50	23 30
Salinity	25·10	28·17	30·44	29 92	17 29	19·74	16 91	17 19	18 30	19·38
Chlorine	13 84	15 59	16 85	16 56	9·56	10·92	9·35	9·51	10 12	10·72

flow of sea-water into the backwater takes place At the bar the salinity of the water was 28·17, 30·44, and 29 92 per mille in the months of January, February and March respectively The corresponding figures for April, May and June were 17 29, 19 74, and 16 91 respectively The greatest variations in salinity occur when the bar is closed since the occasional showers during June–July bring down considerable quantities of freshwater, effecting a notable reduction in salinity On the other hand, intense heat of the summer results in an increase in salinity of the backwater, especially of the pools in the marginal zone, since the volume of water is very much lowered owing to drought

In the absence of any large river opening into the sea in the vicinity of the city of Madras, the salinity of the coastal waters here is much higher than the records for the upper limits of the Bay of Bengal According to Sewell's charts, the maxima and minima are 34 50 (June–August) and 32 00 (September–November) per mille respectively (Sewell, 1929) This is in sharp contrast to what occurs at the head of the Bay, where the surface salinity may be so low as 21 00 per mille, owing to the large volume of freshwater brought down by the Ganges and the Brahmaputra The change from marine to brackish-water conditions is gradual in the Gangetic Delta, while it is rather abrupt at Adyar

Temperature—The maximum and minimum records of temperature of the water are 33 80 and 25 00 degrees Centigrade respectively The temperature is the lowest during the rainy season when the bar is open, and is highest during the summer months May and June From January to March, the temperature of the water is slightly higher than that of the air, while in the succeeding months of April, May and June it is below the air temperature As in the case of salinity, the temperature is also subject to a great amount of fluctuation In the backwater, there is often difference between the readings for the middle and marginal zones, and the surrounding pools. The deeper central zone has a more uniform temperature than the other regions The exposed mud-flats with numerous pools show the greatest amount of variation as they are quickly heated up by sunlight The following readings of surface temperature taken at 12 Noon on a bright sunny day in the month of October (1–10–1934) are illustrative —

Temperature of the sea-water	27° 70 C
Temperature of the water at bar	28°·00 C
Middle zone	29° 20 C
Marginal zone	32°·00 C
Temperature of an isolated pool.	33°·80 C

The maximum difference noted between morning (8 A M) and afternoon (2–3 P M) temperatures is 3 5° during the month of June

The pH values normally vary between 8 and 9 As will be seen from the table, the highest values are observed during the months June and July.

List of Animals Collected from the Brackish-waters of Madras.

The following list does not include the Protozoa and the Rotifera since we have not made any special study of them Only the commonest species of the Copepods obtained are listed The other groups are fairly exhaustive Those species which have been recorded by other authors, but which we have not been able to obtain, are mentioned separately The latest nomenclature has been followed as far as possible

Phylum Porifera

Spongilla sp

Phylum Cœlenterata

Class *Hydrozoa*
Dicyclocoryne filamentata (Annandale) Medusæ only
Campanulina ceylonensis (Browne) Medusæ only
(*Phortis ceylonensis* of certain authors)
Campanularia (Clytia) noliformis McCrady Hydroid only.
Laomedea (Obelia) spinulosa Bale Hydroid only

Class *Scyphozoa*
Acromitus flagellatus (Hæckel) The species is probably the same as *A rabanchatu* Annandale (*vide* Rao, H S , 1931)

Class *Anthozoa*
Order *Actiniaria*
Sub-tribe *Athenaria*
Phytocœtes gangeticus Annandale
Phytocœteopsis ramunnii Panikkar
Stephensonactis ornata Panikkar
Pelocœtes exul Annandale.
Sub-tribe *Boloceroidaria*
Boloceractis gopalai Panikkar
Bunodeopsis sp (not *B strumosa*)
Sub-tribe *Acontiaria*
Aiptasiomorpha sp

Phylum Platyhelminthes

Order *Acœla*
Convoluta sp. ?

Phylum Nemertea

- Order *Heteronemertini*
  - A species belonging to this order is common in the pools of brackish-water all through the year

Phylum Nemathelminthes

- Class *Nematoda*
  - Family *Oncholaimidæ*
    - *Oncholaimus* sp Common free living Nematode The species is different from *O indicus* and *O chilkænsis*

Phylum Annelida

- Order *Polychæta*
  - Family *Hesionidæ*
    - *Ancistrosyllis constricta* Southern
  - Family *Nereidæ*
    - *Lycastis indica* Southern
    - *Nereis glandicincta* Southern
    - *Nereis chilkænsis* Southern
  - Family *Eunicidæ*
    - *Diopatra variabilis* Southern (Fauvel, 1932, considers the species as being synonymous with *D neapolitana*
    - *Marphysa gravelyi* Southern
    - *Lumbriconereis polydesma* Southern
    - *Lumbriconereis* sp
  - Family *Nephthydidæ*
    - *Nephthys polybranchia* Southern
  - Family *Ariciidæ*
    - *Scoloplos* sp
    - *Scolecolepis* sp Probably *S indica* Fauvel
  - Family *Spionidæ*
    - *Polydora ciliata* Johnston
    - *Polydora kempi* Southern
    - *Prionospio cirrifera* Wiren
  - Family *Capitellidæ.*
    - *Heteromastus similis* Southern
    - *Capitella* sp
  - Family *Sabellidæ*
    - *Laonome indica* Southern
    - *Potamilla leptochæta* Southern
  - Family *Serpulidæ*
    - *Hydroides norvegica* Gunnerus.

Order *Oligochæta*

Family *Megascolecidæ*

Pontodrilus bermudensis Beddard

Phylum Polyzoa

Order *Ctenostomata*

Family *Vesicularidæ*

Bowerbankia caudata Hincks

Phylum Arthropoda

Class *Crustacea*

Order *Copepoda*

Only the commonest species are noted

Acartia southwelli Sewell

Pseudodiaptomus annandalei Sewell

Order *Cirripedia*

Division *Operculata* Family *Balanidæ*

Balanus amphitrite Darwin

Order *Schizopoda*

Mysidacea Family *Mysidæ*

Rhopalophthalmus egregius Hansen

Mesopodopsis orientalis (Tattersal)

Order *Amphipoda*

Amphipoda Genuina Gammarina

Grandidierella megnea (Giles)

Grandidierella gilesi Chilton

Paracalliope fluviatilis (G. M. Thomson)

Order *Tanaidacea*

Apseudes sp. not *A. chilkensis*

Order *Isopoda*

Isopoda Genuina

Family *Cirolanidæ*

Cirolana sp. probably *C. pleonastica* Stebbing

Family *Sphæromidæ*

Sphæroma vastator Spence Bate (*S. terebrans* of certain authors.)

Family *Cymothoidæ*

Cymothoa indica Schiodte and Meinert. The species is parasitic in the mouth and gill chambers of *Etroplus maculatus*, *E. suratensis* and *Glossogobius giuris* (Panikkar and Aiyar, 1937)

Family *Ligiidæ*.

Ligia exotica Roux.

Order *Decapoda*

- *Decapoda Natantia*
  - *Tribe Caridea.*
    - Family *Palæmonidæ*
      - *Periclimenes indica* Kemp
      - *Periclimenes demani* Kemp
      - *Leander* sp.
      - *Palæmonetes hornelli* Kemp
      - *Palæmon lamarrei* Milne-Edwards.
    - Family *Alpheidæ*
      - *Alpheus malabaricus* Fabricius
      - *Alpheus paludicola* Kemp
      - *Alpheus* sp *A rapax ?*
  - Tribe *Penæidea*
    - Family *Penæidæ*
      - *Penæus carinatus* Dana
      - *Penæus indicus* Milne-Edwards
      - *Penæopsis monoceros* (Fabricius)
- *Decapoda Reptantia*
  - Tribe *Oxystomata*
    - Family *Calappidæ*
      - *Matuta victor* (Fabricius)
  - Tribe *Brachygnatha*
    - Family *Ocypodidæ*
      - *Ocypoda cordimana* Desmarest
      - *Ocypoda macrocera* Milne-Edwards
      - *Uca (Gelasimus) annulipes* (Latreille)
      - *Uca (Gelasimus) triangularis* (A Milne-Edwards) The species is recorded by Henderson We have not obtained it so far.
      - *Metaplax distincta* (Milne-Edwards)
    - Family *Grapsidæ*
      - *Varuna litterata* (Fabricius)
      - *Sesarma tetragonum* (Fabricius)
      - *Sesarma quadratum* (Fabricius)
      - *Grapsus maculatus* Catesby (Syn *G grapsus*)
      - *Metasesarma rousseauxii* H Milne-Edwards
    - Family *Portunidæ*
      - *Scylla serrata* (Forskal)
      - *Neptunus pelagicus* (Linnæus)
      - *Neptunus sanguinolentus* (Herbst).

- Tribe *Paguridea*
  - Family *Paguridæ*
    - *Clibanarius olivaceous* Henderson
    - *Clibanarius padavensis* De Man
    - *Diogenes* sp *D avarus ?*

Phylum Mollusca

- Class *Lamellibranchiata*
  - Family *Ostreidæ*
    - *Ostrea arakanensis* Sowerby The species is synonymous with *O madrasensis* and *O virginica* of Preston and other authors (*vide* Winckworth, 1931)
  - Family *Mytilidæ*
    - *Modiolus striatula* Hanley
    - *Modiolus undulatus* (Dunker)
  - Family *Arcidæ*
    - *Arca granosa* (Linnæus)
  - Family *Veneridæ*
    - *Meretrix casta* Chemnitz
  - Family *Cuspidariidæ*
    - *Cuspidaria cochinensis* Preston
- Class *Gastropoda*
  - Family *Hydrobiidæ*
    - *Stenothyra blanfordiana* Nevill
    - *Amnicola* (*Alocinma*) *stenothyroides* Dohrn
  - Family *Cerithiidæ*
    - *Potamides cingulatus* (Gmelin)
    - *Melania tuberculatus* (Muller)
  - Family *Nassidæ*
    - *Pygmæonassa orissænsis* (Preston)
  - Family *Aplysiidæ*
    - *Aplysia* sp
  - Family *Hermæidæ*
    - *Stiliger gopalai* Rao

Phylum Chordata

- Class *Pisces*
  - Order *Teleostei*
    - Sub-Order *Malacopterygii*
      - Family *Elopsidæ*
        - *Elops indicus* Swainson
        - *Megalops cyprinoides* (Broussonet)

Family *Chanidæ*
Chanos chanos (Forskal)
Family *Clupeidæ*
Engraulis purava (Hamilton Buchanan)
Stolephorus commersonii Lacepede
Clupeoides lile (Cuv et Val)
Sub-Order *Ostariophysi*
Family *Siluridæ*
Plotosus canius Ham Buch
Macrones vittatus (Bloch)
Macrones gulio (Ham Buch)
Macrones keletius Cuv et Val
Family *Cyprinidæ*
Barbus sophore (Ham Buch)
Barbus dorsalis (Jordan)
Barbus amphibius (Cuv et Val) The species is not represented in our collections, but is mentioned by Raj (1916)
Sub-Order *Haplomi*
Family *Cyprinodontidæ*
Panchax parvus Raj
Aplocheilus melastigma McClelland
Sub-Order *Percesoces*
Family *Scombresocidæ*
Hemiramphus limbatus Cuv et Val
Family *Mugilidæ*
Mugil cephalus Linn
Mugil sp
Family *Sphyrænidæ*
Sphyræna jello Cuv et Val
Sub-Order *Acanthopterygii*
Family *Serranidæ*
Serranus sexfasciatus Cuv et Val
Chanda (Ambassis) ambassis (Lacepede)
Chanda (Ambassis) myops Gunther
Lutjanus johnii (Bloch)
Therapon jarbua (Forskal)
Therapon puta Cuvier
Therapon quadrilineatus (Bloch)
Family *Sillaginidæ*
Sillago sihama (Forskal)

Family *Squamipinnes*
  Scatophagus argus (Bloch)
Family *Mullidæ*
  Upeneus sulphureus Cuv et Val
Family *Gobiidæ*
  Sub-family *Gobiinæ*
  Gobius polynema (Bleeker)
  Gobius melanosticta Day (Not obtained by us, but mentioned by Day.)
  Gobius criniger Cuv et Val
  Glossogobius giuris (Hamilton Buchanan)
  Ctenogobius (*Oligolepis* ?) *acutipinnis* (Cuv et Val)
  Ctenogobius meggitti Hora and Mukerji.
  Acentrogobius neilli (Day)
  Acentrogobius viridipunctatus (Day)
  Oxyurichthys tentacularis (Cuv et Val)
  Apocryptichthys sp Not *A cantoris* Day
  Boleophthalmus boddaerti (Pallas)
  Sub-Family *Eleotrinæ*
  Eleotris fusca (Bl and Schn)
  Sub-family *Periophthalminæ*
  Periophthalmus kœlreutri (Pallas)
  Periophthalmus pearsei Eggert
Sub-Order *Zeorhombi*
Family *Bothidæ*
  Pseudorhombus arsius (Hamilton Buchanan)
  Pseudorhombus javanicus (Bleeker)

Scombriformes

Family *Carangidæ*
  Caranx ciliaris (Bloch)

Jugulares

Family *Blenniidæ*
  Petroscirtes bhattacharyæ Chaudhuri

Scleroparei

Family *Platycephalidæ*
  Platycephalus scaber (Linn)
  Platycephalus insidiator (Forskal)

Chromides

Family *Cichlidæ*
  Etroplus maculatus (Bloch)
  Etroplus suratensis (Bloch)
Sub-Order *Plectognathi*

Sclerodermi

Family *Triacanthidæ*

Triacanthus brevirostris Temm and Schleg.

Gymnodontes

Family *Tetrodontidæ*,

Tetrodon patoca Hamilton Buchanan

Tetrodon inermis Temm and Schleg

Class *Reptilia*

Order *Ophidia*

Natrix piscator (Schneider)

Cerberus rhynchops (Schneider)

Regional Distribution and Range of Fauna

Apart from the regional survey of the fauna of Adyar that follows, the range of distribution of many of the species may be indicated here, especially of those that show great restriction or variation in occurrence. Species that have a wide range of distribution from the bar (even seashore in some instances) up to the inner reaches of the river and the backwater where the water is almost fresh during low tide are —

Acromitus flagellatus
Lycastis indica
Heteromastus similis
Capitella sp
Modiolus striatula
Scylla serrata
Mesopodopsis orientalis
Tetrodon patoca

These species have been obtained from collections made from the river near the Teachers' College and the Engineering College *Acromitus flagellatus* has been observed only during high tide, probably it comes in with the rising tide and retreats with the tidal flow, without having the necessity to remain in freshwater Others have been collected irrespective of tidal influence, *Scylla serrata*, *Mesopodopsis orientalis*, *Lycastis indica* and the Capitellids can remain in water that is nearly fresh Large numbers of young ones of Tetrodons and colonies of Modiola were collected from about two furlongs east of the Saidapet Bridge, the latter in clusters of hundreds from the stony banks of the stream This was in the month of January, 1935, an abnormal year as the rainfall was rather scanty, and the bar was about to close even though the rainy season was only just over. Only Modiolas, Mesopodopsis and the Capitellids appear to be able to breed here in the uppermost reaches of the brackish-water zone among the animals listed previously

Coming down the river for about a mile and a half from the above locality where the water is almost fresh, the marine element in the fauna becomes more marked, and near the Adyar Boat Club the conditions probably range from oligohaline to mesohaline environments The fauna is not rich in the river proper, but the adjoining pools that occur on either side harbour a rich fauna The organisms found in these pools will be considered separately The 'marine' species that are common in this zone of the river are —

Phytocœtes gangeticus
Lycastis indica
Lumbriconereis polydesma
Lumbriconereis sp
Marphysa gravelyi
Penæopsis monoceros
Grandidierella megnæ

The typical brackish-water tract that harbours a rich fauna commences from about half a mile lower down, and consists of that part of the river near the Elphinstone Bridge and the backwater The animals that are found quite close to the bar include only true marine species and are obviously forms that cannot survive great decrease in the salinity of the environment

One usually finds the following animals at or near the bar —

Glycera sp
Ocypoda cordimana
Ocypoda macrocera
Matuta victor
Neptunus sanguinolentus
Neptunus pelagicus
Apylsia sp
Platycephalus insidiator

Clibanarius padavensis is also found but its occurrence in this region is not due to its lack of adaptational power to less saline environments, but only to a preference to a sandy bottom The invertebrate animals that are common in the seashore just opposite the mouth of the river and the vicinity are —

Cavernularia malabarica
Sphenopus marsupialis

Onuphis eremita
Glycera sp.
Donax sp.
Leiodomus vittatus
Littorina sp.
Olivia gibbosa
Albunea semnista
Emerita (Hippa) asiatica
Philyra scabriscula
Ocypoda platytarsis
Ocypoda macrocera

Excepting *Ocypoda macrocera*, none of these species has invaded the brackish-water.

The distribution of many of the species is considerably influenced by the nature of the substratum. Species like *Potamides cingulatus*, *Phytocœtes gangeticus*, *Phytocœteopsis ramunnii*, *Stephensonactis ornata*, *Scylla serrata*, *Uca annulipes*, *Sesarma quadratum*, *Sesarma tetragonum* and a few others are not found in completely sandy areas. They show a definite preference to localities where the bottom consists of sand and mud mixed more or less in equal proportions. However, *Sesarma tetragonum*, *S. quadratum* and *Uca annulipes* are more frequently found in wet mud-banks that are not submerged as all of them are of almost terrestrial habits. The majority of Polychætes are also found in shallow localities of a mixture of sand and mud. *Neptunus pelagicus*, *N. sanguinolentus*, *Matuta victor*, *Clibanarius padavensis*, *Ocypoda cordimana*, *O. macrocera* and *Platycephalus insidiator* are species almost invariably restricted to sandy regions. The south-western fringe of the backwater is characterised by soft black clay that emits hydrogen sulphide and the fauna here is rather sparse. There are practically no animals where the clay is thick, but in other regions where the sub-stratum is loose *Lumbriconereis* sp., *Marphysa gravelyi* and *Prionospio cirrifera* are often common among the Polychætes, and *Stenothyra blanfordiana* and *Pygmæonassa orissænsis* among the Molluscs. The Buckingham Canal, the Cooum, and the brackish-water ditches adjoining them have a poor macroscopic fauna as the water in them is much polluted. The animals that are collected usually from these localities are *Sesarma quadratum* and *Lycastis indica* near the water edge, *Marphysa gravelyi*, *Melanoides tuberculatus* and *Lumbriconereis* sp. in the mud. Small ditches of water near the Cooum bar harbour large numbers of *Potamides cingulatus*. *Metasesarma rousseauxii* is often found crawling amidst the stones near the Napier Bridge.

Bionomical Classification of the Fauna

The backwater and the river may be divided according to the environmental conditions and the habits of the different species into the following groups

I Fauna of the Algal Beds—The backwater and the adjoining pools harbour a rich algal flora consisting of species of ***Enteromorpha*, *Chætomorpha*,** *Gracillaria* and other forms, while the bottom is often covered with dense growths of *Potamogeton* sp The number of animals inhabiting the algæ and the leaves of Potamogetons is very great and they are here collectively designated as the algal-bed fauna As the maximum algal growth is during the summer when the bar is closed and the water still, the animals inhabiting the algæ have corresponding maxima periods in summer The following forms have usually been obtained from the algal beds :—

Boloceractis gopalai
Bunedeopsis sp
Planarian (*Convoluta* sp ?)
Oncholaimus sp
Bowerbankia caudata
Nereis glandicincta
Modiolus undulatus
Stenothyra blanfordiana
Amnicola (*Alocinma*) *stenothyroides*
Cuspidaria cochinensis
Stiliger gopalai
Grandidierella megnæ
Grandidierella gilesi
Paracalliope fluviatilis

Of these the species of Amphipods are obtained in large numbers all through the year. The Molluscs are usually common only during the summer and a few succeeding months The *Planarian* has been noted only in the month of August, and that for a short period None of the other species shows any particular dominance during other periods The algæ amongst which the animals live form the food for many of them

II Fauna of Rocky Substrata—The animals grouped under this head include (1) attached forms like ***Balanus*** and ***Laomedea*** which are found on the boulders of bridges, stones on the banks, etc , (2) species that occur in water where the bottom is stony , and (3) forms that live on stones on the water-edge and are aquatic, amphibious or terrestrial The following are the common species :—

Spongilla sp
Campanularia noliformis
Laomedea spinulosa
Aiptasiomorpha sp
Nereis chilkænsis
Ancistrosyllis constricta
Hydroides norvegica.
Modiolus striatula
Ostrea arakanensis
Balanus amphitrite
Sesarma quadratum
Clibanarius olivaceous
Grapsus maculatus
Ligia exotica
Cirolana sp

Of these the Sabellid and Hydroids are common only when the bar is open Goboid fishes like *Acentrogobius viridipunctatus*, *Ctenogobius meggitti* and *Glossogobius giuris*, and the Ciclid fish *Etroplus maculatus* and *E suratensis* are often collected from localities with a stony bottom Their eggs are found attached to the stones, empty shells, etc The snake *Natrix piscator* is fairly common on the southern banks of the river

III The Free-Swimming Fauna —The following animals constitute the free-swimming element of the fauna —

Dicyclocoryne filamentata (Medusæ)
Campanulina ceylonensis (,,)
Acromitus flagellatus
Mesopodopsis orientalis
Rhopalophthalmus egregius
Periclimenes indica
Periclimenes demani
Leander sps
Palæmon lamarrei
Penæus carinatus
Penæus indicus
Penæopsis monoceros
Copepods
Fish

IV Fauna of the Marginal Zone —The animals that inhabit the marginal zone of the backwater include numerous species , the majority of them are inter-tidal forms found in the mud-flats or the water edge Most of the species are either amphibious or terrestrial, or the species are capable of surviving temporary exposure to air They are highly resistant and are endowed with great powers of adaptability The following species may be noted —

Phytocœtes gangeticus
Clibanarius olivaceous
Clibanarius padavensis
Sesarma quadratum
Sesarma tetragonum
Metasesarma rousseauxii
Metaplax distincta
Varuna litterata
Uca annulipes
Stenothyra blanfordiana
Amnicola stenothyroides
Potamides cingulatus
Periophthalmus pearsei
Periophthalmus kœlreutri
Boleophthalmus boddærti

The species of *Clibanarius*, *Sesarma quadratum*, *Uca annulipes*, *Potamides cingulatus*, the Hydrobiid Molluscs, and *Boleophthalmus boddærti* are the commonest species found near the edges of the Adyar backwaters, especially when the mud-flats are exposed The marginal species found near the mouth of the Cooum are *Potamides cingulatus*, *Melania tuberculatus*, *Metasesarma rousseauxii*, *Ocypoda cordimana*, *Sesarma quadratum* and *Uca annulipes*

V Fauna of the Middle Zone —Passing on to the middle zone of the backwater, the following species are commonly met with —

Pelocœtes exul
Marphysa gravelyi
Diopatra variabilis
Lumbriconereis sp
Heteromastus sp
Meretrix casta
Pygmæonassa orissænsis
Matuta victor
Scylla serrata

In addition, most of the free swimming species of Crustaceans, and fishes are also obtained from the middle zone The anemones *Phytocœteopsis ramunnii*, *Stephensonactis ornata* and *Phytocœtes gangeticus* are found between the marginal and middle zones of the backwater The last mentioned species has also been obtained from exposed mud-flats with very little water

VI The Mud-Burrowing Fauna—Most of the species listed above under the fauna of the marginal and middle zones are either mud-burrowing in habits or are capable of temporarily remaining in the mud The following species are typical burrowers —

(*a*) Under water—
- *Phytocœtes gangeticus*
- *Phytocœteopsis ramunnii*
- *Stephensonactis ornata*
- *Pelocœtes exul*
- *Marphysa gravelyi*
- *Diopatra variabilis* (also tube-dwelling)
- *Lumbriconereis* sp
- *Prionospio* sp
- *Capitella* sp
- *Heteromastus* sp

(*b*) Outside water—
- *Sesarma quadratum*
- *Sesarma tetragonum*
- *Metasesarma rousseauxii*
- *Varuna litterata*
- *Uca annulipes*
- *Ocypoda cordimana*
- *Ocypoda macrocera*
- *Pontodrilus bermudensis*

Species that can temporarily remain under the mud in the water for varying periods are —
- *Apseudes* sp
- *Meretrix casta*
- *Scylla serrata*
- *Alpheus malabaricus*
- *Alpheus paludicola*
- *Penæus indicus* (Young ones)
- *Penæus carinatus* (Young ones)
- *Penæopsis monoceros*
- *Leander* sp
- *Periophthalmus pearsei*
- *Boleophthalmus boddærti*
- *Platycephalus scaber*

The following species creep about near the water-edge :—

Clibanarius olivaceous
Clibanarius padavensis
Potamides cingulatus
Stenothyra blanfordiana
Amnicola stenothyroides

VII Species Capable of Aerial Respiration.—Many of the animals inhabiting the mud-flats are either amphibious or terrestrial in habits Though they belong to groups of animals that are primarily aquatic, they are capable of varying degrees of aerial respiration The crabs and the Goboid fishes are the most remarkable among them as they show a series of adaptations designed for aerial respiration, and some of the Crustaceans are thoroughly terrestrial and can respire only outside water The following species mostly remain outside water —

Crustacea—
Grandidierella megnæ
Grandidierella gilesi
Paracelliope fluviatilis
Ligia exotica
Uca annulipes
Ocypoda cordimana
Ocypoda macrocera
Metaplax distincta
Metasesarma rousseauxii
Sesarma quadratum
Sesarma tetragonum
Grapsus maculatus
Varuna litterata
Clibanarius olivaceous
Clibanarius padavensis

Among these species, *Ocypoda cordimana*, *O macrocera*, *Grapsus maculatus*, and *Ligia exotica* are almost completely terrestrial

Fishes—
Periophthalmus pearsei
Periophthalmus kœlreutri
Boleophthalmus boddærti

Other Invertebrates—
Lycastis indica
Capitellids

Potamides cingulatus
Stenothyra blanfordiana.
Amnicola stenothyroides

In addition, the following species can survive exposure to air for different periods varying according to the species —

Phytocœtes gangeticus
Scylla serrata
Neptunus sanguinolentus
Palæmon lamarrei
Penæopsis monoceros
Oxyurichthys tentacularis
Ctenogobius (Oligolepis ?) acutipinnis
Platycephalus scaber

VIII Fauna of Isolated Brackish-water Pools —The pools of brackish-water in association with the backwater and the river are of three kinds, they are —(1) Small pools on the fringes of the backwater, harbouring a rich algal flora during the summer, and at other times having the same environmental conditions as the backwater, (2) Salt pools that occur on either side of the river up to an extent of about three miles from the river mouth, and (3) Pools in which the water is only very slightly brackish or completely fresh, occurring higher up the river and containing freshwater organisms in addition to a few brackish-water species that enjoy a wide range of distribution (compare above)

The first type of pools contains the following species, excluding the alga-inhabiting forms which have been given separately

Phytocœtes gangeticus
Phytocœteopsis ramunnii
Campanulina ceylonensis
Clibanarius olivaceous
Paracalliope fluviatilis
Grandidierella megnæ
Potamides cingulatus

The temperature fluctuations are rather high in these pools as has already been pointed out.

The pools belonging to the second category are numerous, but a large and typical one is that found near the Adyar Boat Club, the fauna of which during the different seasons was studied by us in detail This pool is situated in somewhat marshy soil just adjoining the Adyar River on its west and the Buckingham Canal to the south, and it is about half a furlong

long The pool gets filled up by the November rains, but the level of the water gradually falls in the succeeding months The depth of water is about 2-2½ ft during November-December period (this is about the maximum depth), but by February, the depth is only a few inches The pools are almost without water by about March Owing to percolation of water from the river, the water in the pool remains brackish all through the year and the fauna is what is characteristic of the brackish-water From November to March, the following species are obtained from these pools —

Acromitus flagellatus
Phytocœtes gangeticus
Lumbriconereis polydesma
Lumbriconereis sp
Lycastis indica
Marphysa gravelyi
Heteromastus similis
Prionospio cirrifera ?
Mesopodopsis orientalis
Periclimenes indica
Palæmon lamarrei (Stray individuals only)
Paracalliope fluviatilis
Sesarma quadratum
Sesarma tetragonum
Aplocheilus melastigma
Acentrogobius neilli
Acentrogobius viridipunctatus

By April, the conditions of the pool change very much since most of the aquatic species perish with the drought The interesting point about this pool is that unlike the pools in the mud-flats that completely dry up during the summer, the bottom remains slightly moist even in the hottest months of the year as a result of percolation of water from the river Contrary to what happens in the mud-flats, the muddy substratum does not become cracked up in the usual manner During this period, the pool has a certain amount of resemblance to a salt marsh, and as is usual with the salt marsh fauna, typical terrestrial species are met with in large numbers Numerous insects, among which the one frequently encountered is a Forficulid, and a spider belonging to the genus *Olios* (Family Sparassidæ) and probably to the widely distributed Oriental species *Olios lamarcki* (Latreille), are quite common in the marshy mud until about the month of October, when again the pool gets filled up by the rains, thus giving place to the other set of animals Since the soil is wet in the middle of the pool even during the summer, species like *Lumbriconereis* sps, *Phytocœtes gangeticus*, and the Capitellids do not actually perish during drought, but remain alive and inactive in the wet mud

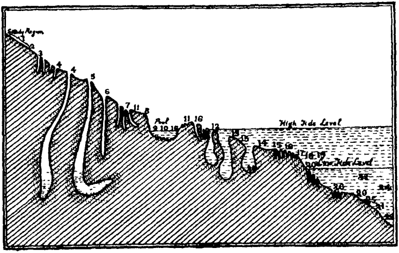
The pools belonging to the third category are much smaller in area and poorer in fauna than those described before The following species are noted from them —

- *Lycastis indica*
- *Lumbriconereis* sp
- *Stenothyra blanfordiana*
- *Amnicola stenothyroides*
- *Indoplanorbis exustus*
- *Melania tuberculatus*
- *Mosquito larvæ* (Culex group)
- *Chironomid larvæ*

In addition to these species, tadpoles and adults of the common frog *Rana cyanophlyctes* Schneider have also been met with in these pools during the rainy weather

Vertical Distribution of Animals

I Inhabitants of the Mud-flats —The vertical distribution of the inhabitants of the mud-flats is represented in an imaginary section passing



TEXT FIG 2

through a mud-flat. The different levels at which the burrowing species occur are indicated in the figure. All the species marked do not occur in any one particular locality. The groups of animals that show a distinct zonation in the inter-tidal zone are the crabs. The Ocypods, *O. cordimana* and *O. macrocera*, are the species that occur farthest from the water-level near the bar; in other places the corresponding species is *Sesarma tetragonum*, which inhabits deep burrows. The habits of the Ocypods and those of *Sesarma* are by no means similar; for, while the former mostly remain outside the burrows, retiring into them only for safety, the latter rarely come out. *Gelasimus (Uca) annulipes* and *Sesarma quadratum* inhabit burrows above water edge. In all the burrowing crabs, the depths of the burrows are such that they run on a line with the low tide level so that there will be a little water in them even during low tide. Among the Polychætes, *Lycastis indica* and the Capitellids are often observed above the water-level. *Clibanarius padavensis*, *C. olivaceous* and *Scylla serrata* are inter-tidal in habits, but the last mentioned is a swimming form and hence cannot be said to have any restricted occurrence.

II. Plankton.—The following notes on the plankton of the Adyar backwaters are based upon a number of collections made between November 1933 and October 1936. An ordinary muslin tow-net was used for making collections, which, on the average, were made once a fortnight. During the August-January period when the planktonic organisms are particularly noticeable, tow-netting was done almost every week during the years 1934 and 1935. On the other hand, the number of collections made during the summer months is rather low; and often, the tow-net water yielded nothing. Planktonic study not being our main objective, the observations made here are intended only for pointing out some of the more important features of the plankton. We have not paid attention to the study of the Protozoa; of the Copepods, only the commonest species have been noted. One great difficulty experienced was in tow-netting small pools of brackish-water; these pools have been eliminated from the study; but several collections have been made from the large salt pool near the Boat Club. There is not the least doubt that variations take place from year to year in the constituent elements of the plankton in the different months depending upon the changes in the rainy season and their influence on the time of opening and closing of the bar. An approximate idea of the nature of the plankton during the different months may be gathered from the following summary of our records.—

November Bar just open
Acromitus flagellatus Ephyræ Common
Campanulina ceylonensis Rare
Rhopalophthalmus egregius Swarms in 1933
Mesopodopsis orientalis Swarms
Penæus carinatus Post-larval stages Common
Penæus indicus. Post-larval stages Common
Clupeid larvæ Common
Therapon jarbua Young ones
Acentrogobius neilli Larval and Post-larval forms
Aplocheilus melastigma Young and adults

December Bar open
Acromitus flagellatus Ephyræ Common
Dicyclocoryne filamentata Rare.
Penæus carinatus Post-larval and young ones Plenty
Penæus indicus. Post-larval and young ones Plenty
Mesopodopsis orientalis Common
Peciclimenes indica Rare
Cirripede nauplii (Probably of *Balanus amphitrite*) Common
Pseudodiaptomus annandalei Common
Ocypode megalopæ (*Ocypoda cordimana* ?)
Therapon jarbua Young ones
Therapon quadrilineatus Young ones
Clupeid larvæ (Engraulis and Stolephorus)
Young mullets
Aplocheilus melastigma Post-larval and young ones

January Bar open
Acromitus flagellatus. Young ones Plenty
Campanulina ceylonensis Rare
Penæus carinatus. Post-larval and young ones Common
Penæus indicus Post-larval and young ones Common
Periclimenes indica Rare
Pseudodiaptomus annandalei Common
Post-larval Goboids Common
Aplocheilus melastigma Young and adult Common
Young mullets Rare

February Bar open, but very narrow
Campanulina ceylonensis Rare
Penæus indicus Young ones Common.
Penæus carinatus Young ones Common

Young mullets Rare
Periclimenes indica Rare
Veliger larvæ Rare
Mesopodopsis orientalis
March Bar almost closed, but sea-water may get in during high tide
Aplocheilus melastigma Young ones Common
Acartia southwelli Common
Penæids Young ones Rare
Veliger larvæ Common
April Bar closed
Campanulina ceylonensis Rare
Acartia southwelli Plenty
Pseudodiaptomus annandalei Rare
Veliger larvæ Common
Mesopodopsis orientalis Rare
May Bar closed
Periclimenes indica Rare
Pseudodiaptomus annandalei Rare
Veliger larvæ Plenty
June Bar closed
Campanulina ceylonensis Common
Veliger larvæ Common
Periclimenes demani Rare
Periclimenes indica Common
Mesopodopsis orientalis Common
Palæmonetes hornelli ? Rare
July Bar closed
Campanulina ceylonensis Common
Acœlous planarian (*Convoluta* sp ?) Rare
Acartia southwelli Common
Periclimenes indica Common
Mesopodopsis orientalis Common
Pseudodiaptomus annandalei Rare
Leander sp Young ones Common
August Bar closed
Campanulina ceylonensis Common
Acœlous planarian Large numbers
Periclimenes indica Common
Mesopodopsis orientalis Common
Aplocheilus melastigma Young ones
Acentrogobius neilli Young ones

September Bar closed
Acromitus flagellatus Ephyræ
Campanulina ceylonensis Swarms
Copepod nauplii Large numbers
Pseudodiaptomus annandalei Common
Acartia southwelli Rare
Acœlous planarian Rare
Penæopsis monoceros Very young ones Common
Mesopodopsis orientalis Common

October Bar usually closed, but may open during this month
Acromitus flagellatus Ephyræ Common
Campanulina ceylonensis Common
Copepods Numerous (Several species)
Mesopodopsis orientalis Common
Acentrogobius neilli Young ones Common
Acentrogobius viridipunctatus Young ones Common
Periclimenes indica Rare
Penæopsis monoceros Young ones Common

General Conclusions on the Fauna

The list of animals given previously will clearly illustrate the predominantly marine character of the fauna of Advar and the adjoining brackish-waters of Madras Of about 92 species of Invertebrates noted, more than eighty species belong to groups of animals that are typically marine The freshwater species which have more or less acclimatised to the brackish-water conditions are thus comparatively few here, this constitutes the most important difference between the fauna of an estuarine brackish-water tract and that of a salt marsh In the latter, the animals which are of typical freshwater habitat, and terrestrial species that have secondarily taken to an aquatic mode of life are quite numerous and show varying degrees of adjustment to saline environments In the Advar fauna, the noteworthy groups of freshwater animals which have secondarily taken to brackish-water life are the members of the family Hydrobidæ among the Mollusca and some of the Palæmonidæ among the Crustacea

Among the 64 species of fishes, only seven freshwater forms are noted The others include several casual or seasonal migrants from the sea, while the majority of them are more or less permanent inhabitants of the back-water The true brackish-water species have been caught when the bar is open and when it is closed, and in most of them, the young as well as the adult fish have been met with Marine species like *Stolephorus commersoni*, *Sphyræna jello, Serranus sexfasciatus, Lutjanus* sp., *Therapon quadrilineatus, Therapon puta, Upeneus sulphureus, Scatophagus argus, Caranx ciliaris, Pseudorhombus javanicus, P. arsius* and *Triacanthus brevirostris* have been obtained only during the months when the bar is open and the salinity high. The freshwater species are the two Chiclids, *Etroplus maculatus* and *E. suratensis, and Macrones vittatus, Panchax parvus, Aplocheilus melastigma, Barbus sophore* and *Barbus dorsalis*. All of these species breed in brackish-water.

Breeding Habits

Many species inhabiting the Adyar backwaters are capable of breeding all through the year, but a period of intense reproductive activity is seen in many of the inhabitants. This is determined by the extent to which the environmental conditions are suitable for the breeding of any particular animal. Thus most fish cannot breed when the backwater and the river are partially dried up, nor can the Gastropods with their densely packed gelatinous egg masses breed under flooded conditions. Ripe sex cells or embryos have been observed in the following animals during all months of the year:—

Pelocœtes exul
Phytocœtes gangeticus
Phytocœteopsis ramunnii
Stephensonactis ornata
Marphysa gravelyi
Lycastis indica
Lumbriconereis sp.
Diopatra variabilis
Mesopodopsis orientalis
Grandidierella megnæ
Grandidierella gilesi
Paracalliope fluviatilis.
Clibanarius padavensis
Clibanarius olivaceous.
Potamides cingulatus
Stenothyra blanfordiana
Amnicola stenothyroides.
Stiliger gopalai.
Meretrix casta.
Cymothoa indica.
Cirolana sp.
Aplocheilus melastigma.

Panchax parvus.
Etroplus maculatus
Etroplus suratensis
Acentrogobius neilli
Acentrogobius viridipunctatus

The groups of animals that show great intensity in reproductive activity during particular seasons are the crabs, Molluscs and the fishes Among the Brachyura, only the Grapsoid and Ocypod crabs breed in the brackish-waters of Madras Ovigerous females belonging to different species have been collected from December to March The Pagurids are perennial spawners Among the Caridea, ovigerous females of *Periclimenes indica* have been obtained only from April to July Very young ones of *Alpheus malabaricus* are very common in the backwater during January and February, and this species also appears to breed under brackish-water conditions *Penæus indicus* and *P carinatus* do not attain sexual maturity in the backwater, but their young ones are noticed in fairly large numbers during the months when the bar is open (compare plankton records) * In contrast with this is another Penæid, *Penæopsis monoceros*, which appears to breed in the brackish-water as judged by the fact that numerous young specimens 15 to 20 mm long are obtained in tow-net collections taken in September and October, about six months after the bar is closed

Most of the fish show an intense reproductive activity soon after the monsoon in November Large numbers of young ones of *Acentrogobius neilli*, *A viridipunctatus*, *Gobius* sps and *Mugil* sps have been obtained in tow-nets during November and December Along with them are found larval and post-larval stages of Clupeid fish which are brought into the backwater from the sea Young ones of *Aplocheilus melastigma* are obtained during almost all the months of the year, especially a day or two after any shower Rains have a remarkable influence over the breeding in most fishes Species like *Acentrogobius neilli*, *A viridipunctatus*, *Etroplus maculatus*, *E suratensis*, *Panchax parvus*, *Aplocheilus melastigma*, etc , spawn intensively even during the summer months if there be occasional heavy rains

The optimum season for breeding of Molluscs is the summer During the months March, April, May, June and July, the egg cases of many Gastropods are common in the backwater Large numbers of young ones of *Potamides cingulatus* and *Meretrix casta* are noticed in July and August. *Stenothyra blanfordiana*, *Amnicola stenothyroides* and *Stiliger gopalai* exhibit enormous powers of reproduction, though they breed all through the year, they have periodical phases of intensive propagation determined by the monsoon, salinity and other environmental conditions

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* For habits of brackish-water prawns, *vide* Panikkar, 1937 *b*.

The subject of breeding in the common brackish-water species of Madras is dealt with in detail in another study by us † The summary of our observations is given below —

1 Breeding of animals of the brackish-waters of Madras is not particularly confined to any definite part of the year, actively reproducing species are met with during all seasons

2 The following types of breeding are noted —

(*a*) Continuous breeding throughout the year occurring more or less uniformly and irrespective of seasons

(*b*) Continuous breeding with a marked season of higher activity during one part of the year than the remainder

(*c*) Breeding season confined to some definite part of the year

(*d*) Discontinuous breeding occurring all through the year, spawning often taking place irregularly, mostly determined by the rains

Discussion

General Considerations —The interesting feature of the fauna of the brackish-water is the intimate association of animals of the sea, backwater and freshwater for life in a common habitat The animals of marine origin constitute the largest number of species as most of them are either present in the sea or are represented there by closely related species The number of marine animals that have invaded the brackish-water is greater in the tropics than in temperate regions Annandale (1922) mentions that the aquatic fauna of Europe is easily divisible into the freshwater and marine faunas, and that with the exception of *Palæomonetes varians* in brackish-water in North Europe, and ***Mysis relicta*** and a few other species of estuarine Molluscs in different parts of Europe, the separation of marine and freshwater faunas is a constant feature Recent studies of the brackish-water fauna of Europe have shown, however, that this statement of Annandale is not altogether correct The contributions of Redeke (1933) on the fauna of the Zuider Sea, of Remane (1934) on the Baltic Sea, of Sick (1933) on the brackish ditches of North Germany, and of Brandt, Wundsch (1933), Lundbeck (1932), Sergestale (1934) and others on the different brackish tracts of Europe have shown that a fairly large number of characteristic marine and euryhaline species exist in Europe inhabiting waters of low salinity The conditions in England are also more or less similar as shown by the studies of Allen and Todd (1900 and 1902), Percival (1929), Stammer (1928), Ellis (1932), Robson (1925) and Fraser (1932) on the estuarine fauna, of Nicol (1936) on the fauna of the brackish lochs of Scotland, and of Lambert (1930) and Nicol (1935) on the animal life of the salt marshes adjoining sea coasts or estuaries It is clear from all these papers that a more or less distinct brackish-water fauna is present in the temperate regions as well It must, however, be admitted that as compared to the tropics, the brackish-water species are fewer in numbers and less in variety in the land-locked seas, estuaries, backwaters and salt marshes of the temperate regions As pointed out by several observers, the penetration of a large number of marine animals into waters of low salinities is a characteristic feature of the tropics, and the numbers of species inhabiting brackish-water are so many and representative of almost all the major marine invertebrate phyla except the Echinodermata An interesting fact regarding the tropical brackish-water fauna is the occurrence of numerous adaptations in the mode of life of animals of marine origin, which serve to facilitate their life in these peculiar environs

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† "Observations on Breeding in Brakish-water Animals of Madras" By N. Kesava Panikkar and R Gopala Aiyar (Unpublished).

Acclimatisation of Marine Animals to Fresh and Brackish-Waters —It is almost universally accepted that the present freshwater fauna has been derived to a large extent from ancient marine animals Many of them have penetrated into freshwater through media of progressively decreasing salinity as found at the meeting places of large volumes of freshwater and sea water like the openings of big rivers or backwaters Most of the modern brackish-water organisms are forms that migrated from the sea into the brackish-water at a very recent geological epoch , often, we find along with them, numerous marine species capable of surviving in the brackish-water. We find in every tropical backwater, tidal creek, or estuary, an active and aggressive attempt on the part of many marine species to secure a permanent foot-hold either in the semi-aquatic mud-flats and mangrove swamps or in the salt marshes with peculiar environmental conditions of fluctuating salinity, temperature and hydrogen-ion concentration Many explanations have been suggested to explain this peculiar phenomenon of the tropics , but as pointed out by Annandale (1922) the factors contributing to this must necessarily be varied, and it is perhaps necessary to study the known instances individually before any definite view is taken The conditions necessary for the successful colonisation of the brackish-water are many and may now be considered

Sollas (1883 and 1905) in his classical discussion on the origin of freshwater faunas, emphasized the current strength of rivers as the chief obstacle to the progress of marine animals into freshwater He pointed out that an animal must either be fixed or strong enough to withstand the current of streams if it should establish itself in fresh-water This must be true of the larvæ as well as the adults, the epiplanktonic ciliated larvæ of marine Invertebrates being extremely unsuitable for life in a flowing stream Hence, only those animals as have got rid of the free-swimming larval stages, by an abbreviation of the life-history, were successful in establishing in the freshwater The absence of free eggs and larvæ from the freshwater plankton is explained by this theory, and the larger sizes of eggs of freshwater animals as compared with their marine relatives is also explained as an attempt at further acquisition of yolk to cope with the curtailment of life-history While explaining some of the important differences between freshwater and marine animal life, this theory does not explain the difference between the temperate and tropical conditions This was attempted much earlier by von Martens (1858) who emphasized that the freshwater environment with its alternative liability to periods of freezing and desiccation, is more severe than that of the sea The difference between the cold and hot seasons is very great in the cold countries, while a more even temperature conditions prevail in the tropics , hence acclimatisation was easier here than in the cold countries where extreme temperature conditions prevail In addition to these two explanations, Needham (1930) made the interesting suggestion that there is a third factor limiting the penetration of marine animals into freshwater, *viz* , that of the inorganic deficiency of the freshwater from the point of view of the larval development of marine animals Based on the experiments of Pouchet and Chabry (1889), Herbst (1897), Rapkine (1927), Ranzi (1930) and his observations on the phosphate contents of developing eggs, he pointed out that the developing planktonic larvæ of marine Invertebrates depend upon the inorganic contents of sea-water for certain items of nutriment Proper development and metamorphosis would be impossible without the supply of calcium, phosphates, etc , inorganic materials not available in freshwater Penetration into freshwater is possible only for those marine animals that have so perfected their development as to be independent of the environment for their inorganic requirements

The three theories summarised above overlooked another important aspect of the problem—the question of osmotic regulation of marine animals on which attention has been focussed in recent years by the work of Schleiper (1929, 1929 *a*, 1930 and 1935), Dakin (1908, 1908 *a*, 1931 and 1935), Schwabe (1933), Adolph (1925, 1926 and 1930), and others The most important physiological difference between freshwater and marine organisms is that in the osmotic pressure relative to the external medium. The body fluids of marine invertebrates have almost the same osmotic pressure as that of the sea-water in which those animals live (Schleiper, 1930), in many instances, this pressure is slightly higher than that of the surrounding medium as shown by recent investigations (Dakin, 1935) These animals allow a free interchange of body fluids with the sea-water, and changes in salinity of the external medium hence affect the osmotic concentration of the body fluids All freshwater and numerous brackish-water animals, as also the marine fishes, have developed a power of regulation of osmotic pressure that keeps their body fluids in a permanent state of hypertonicity irrespective of the low concentration of the medium that bathes the animal When the salt content of the environment is lowered, the higher osmotic pressure of the body fluids of marine invertebrates is not maintained owing to the passage of water into the interior and loss of salts by diffusion This would go on until a state of isotonicity is reached, a condition in which the animal may not survive unless a greater concentration of the body fluid is maintained by some regulating mechanism Thus the colonisation of brackish-water and freshwater is made possible only with the development of osmoregulatory powers as poikilosmoticity would be fatal in hypotonic media

Exact data are not yet available regarding the energy requirements for the maintenance of osmoregulatory powers in aquatic animals In several cases, however, there is a relationship between the salt content of the external medium and the oxygen consumption As shown by Schleiper (1931), Beadle (1931), Lowenstein (1935) and others, there is a rise in the amount of oxygen consumed when marine animals are transferred to media of lower concentrations, the rise gradually goes on until it reaches a maximum and then remains constant at a level above the normal The deleterious effects of oxygen tension combined with reduction in salinity of the environment have been clearly demonstrated by Schwabe (1933) for the crab *Carcinus mœnas* This increase in oxygen requirements has a great bearing on the problem of survival in the brackish-water Integumental regulation plays an important rôle in the maintenance of the steady state Pantin (1931) has observed that the presence of calcium in the water is of considerable advantage to the estuarine Platyhelminth *Gunda ulvæ* in overcoming the adverse effects of salinity fluctuations All these point to the conclusion that the factors involved in the entry of marine animals into brackish-water and freshwater are many and cannot easily be reduced to any single theory

In the light of what has been said above, the relative advantage of the tropics for the inward migration of marine organisms may be explained a being due to various reasons We consider that the temperature factor is of the greatest importance, for, in addition to the relative evenness as suggested by von Martens, the differences between the air, freshwater and ocean temperatures are comparatively small in the tropics Not only was this advantageous in the successful colonisation of brackish and freshwater, but also in the assumption of amphibious and terrestrial modes of life by several littoral marine animals (*cf* Pearse, 1929 and 1936) The greater rainfall of the tropics and the presence of large rivers bringing down an immense amount of fresh water into the sea, have considerably altered the coastal salinities of the tropics and this has endowed the tropical marine animals with great powers of adjustment as they are under the constant influence of salinity fluctuations Sewell (1934) shows that this lowering of salinity at the head of the Bay of Bengal where the Ganges and Brahmaputra open, affects even up to a depth of about fifty fathoms The great change in the coastal salinity as a consequence of the monsoon in the coasts of Indo-China is also mentioned by Pearse (1932 *a*) The effects of this prolonged acclimatisation of marine animals to frequent changes in salinity would be a gradual change in their physiology from stenohalinism to euryhalinism, and from poikilosmoticity to varying grades of homoiosmotic behaviour, depending upon the species concerned and the exact conditions of the environment Only those species of marine invertebrates which have thus responded to the influence of the environment by a gradual assumption of independence over the osmotic concentration of the environment have succeeded in colonising brackish-waters The inorganic materials washed down into the sea by the intense rainfall and the numerous large rivers, support a rich Diatom flora which increases the food resources of the coasts and thereby attract numerous marine animals (Sewell, 1934) From the description of the area on which this study is based, it will be clear that the coastal salinity is not lowered to any appreciable extent, there being no large river in the vicinity of the city of Madras, and the rainfall being comparatively poor The conditions here would seem to favour the temperature factor more than anything else, since the brackish-water fauna is as representative and predominantly marine as that of the Gangetic Delta or of the Chilka Lake

Integumental Adaptations —The changes attendant upon the migration of marine animals into brackish and fresh waters are many, but from the point of view of their morphology, the important among them are the integumental adaptation and the strengthening of the respiratory system by the development of accessory structures to cope with increased oxygen requirements Most brackish-water animals have well-developed mucus secreting devices which effectively guard against sudden changes in salinity by preventing the passage in or out of water for a certain period Paul Bert (1871 and 1885) made the interesting discovery that eels, which were carelessly handled so that the mucus was completely removed, were no longer able to withstand sudden changes from fresh-water to sea-water and *vice versa* (Dakin, 1935) This has been corroborated by the interesting series of experiments of Duval (1925) The power of mucus secretion is widely prevalent amongst aquatic animals, but it is especially well developed in euryhaline and brackish-water species Mucus-cells in the body-wall are remarkably developed in the brackish-water Halcampactids of Adyar, but they are comparatively few and insignificant in a related marine species (Panikkar, 1936, 1937 and 1937 *c*) The Polychætes, *Lycastis indica*, *Diopatra variabilis* and certain others occurring here have also got mucous glands on the body-wall which are remarkably developed, while there is not a single Gastropod of Adyar that is not capable of copious mucus secretion Many species remain enveloped in mucus whenever environmental conditions are adverse, similar to what Duerden (1906) observed in certain corals The prominence and wide-spread occurrence of such external secretory structures in brackish-water species, and the way they are brought into action when animals are transferred to media of varying salinities, would indicate that they are of great advantage to these animals In the case of species that are under the constant danger of being left exposed for fairly long periods, the presence of mucus would also undoubtedly prevent desiccation

Respiration.—Several observers have shown that the oxygen content of shallow brackish-waters and salt marshes is low as the temperature is high in small volumes of water Unfortunately, we have not made studies on the oxygen content of the water, but having observed the high thermal limits to which the pools of brackish-water get heated up, and the occurrence of decaying matter in the river and backwater, there is reason to believe that the oxygen present in the water is low This raises another problem of survival of the brackish-water organisms The predominance of the amphibious element in the Adyar fauna was emphasized in an earlier section, it was shown that the species inhabiting the marginal zone or the actual water edge are many and varied, and larger in communities than those that inhabit the deep water and rely completely on aquatic respiration The animals which have developed extensive means of aerial respiration are the crabs and fishes The proportion of oxygen to the total volume is much higher in air than in water while the oxygen content of the air is about 20%, water under normal conditions of temperature holds only

5 to 10 c c of oxygen per litre Winterstein (1921) has indicated that air is more favourable for oxygen absorption than water which, in turn, is better suited than air for carbon dioxide liberation (*cf* Carter, 1931) In general, the respiratory changes that we find in brackish-water animals are caused by the growth of organs of aerial respiration, and not the increased development of gills for aquatic respiration According to Carter and Beadle (1931) the accessory respiratory organs usually developed in fishes are chiefly organs of oxygen absorption, while the original gills discharge the function of carbon dioxide liberation These additional structures are internal in those animals since they still live in an aquatic medium, in shallow water or at the water edge The changes that have taken place in animals which became slowly adapted to respire in air are (1) the development of additional structures like arborescent folds, etc., (2) devices to maintain the dampness of the epithelium, and (3) devices to prevent evaporation of water from the respiratory surface Amongst the Adyar fishes, organs for aerial respiration are present in the form of vascularised walls of gill chambers, gill septa, etc, in *Periophthalmus kœlreutri*, *P pearsei* and *Boleophthalmus boddærti* In the last species, the body is covered by numerous minute papillæ which have a respiratory function (Harms, 1929) The Amphipods of Adyar, though amphibious in habits, do not seem to have any special structural modification in their respiratory organs The Isopod *Ligia exotica*, though depending completely on aerial respiration, is not found far away from the water edge The thinly chitinized endopodites of pleopods in the aquatic Isopods function as lung in the case of terrestrial species (*cf* Verhoef, 1919) Bepler (1909) finds that they are provided with glands at their bases, the secretion of which keeps them moist The air-breathing capacities of several Decapods are well known, among the crabs, we find a series of adaptations intended for this purpose Structural adaptations are absent in Macrurous species, though some forms, like *Penæopsis monoceros* are capable of remaining outside water in a healthy condition for fairly long periods The Anomura of Adyar are all amphibious and respire partly in air The gills are normal in most Decapods except in completely terrestrial genera The Grapsidæ and the Ocypodidæ, which are either amphibious or are completely terrestrial, show a common modification directed to retaining water in the gill chamber (Carter, 1931). The abnormally developed hairs near the opening of the gill chamber in *Sesarma*, *Cardisoma* and *Uca* (*Gelasimus*) (Ortmann, 1901), the spongy structures on the walls of the gill chamber in *Gecarcinus* and *Ocypoda* (Winterstein, 1921), and the peculiar fold at the floor of the gill chamber in *Uca* (Jobert, 1876) are all disigned for this purpose Enlargement of

the gill chamber is seen in many brackish-water species like *Gecarcinus* (Calman, 1911), *Uca* and *Cardiosoma* and an upper lung chamber and a lower gill chamber are distinct in *Gecarcinus* (Calman, 1911, Carter, 1931) Vascularised epithelial folds that function as accessory organs are met with in the gill chambers of *Gelasimus* (*Uca*) (Jobert, 1876), *Cardiosoma* and *Ocypoda* (Zimmer, 1926-27), and lastly, special apertures that assist the entrance of air are found in the chambers (usually the posterior part) of *Ocypoda*, many Catametopa, and *Graspus* (Muller, 1863, Ortmann, 1901) All these modifications have not much affected the gills proper, and as a rule, the gill chambers are provided with air in the case of air-breathing forms, and not water Carter (1931) suggests that the need for adaptations designed to retain water in the gill chamber is probably caused by the necessity to keep the vascular folds damp

Exposure and Desiccation—We have found from field observations as well as experiments with several species, that many of the brackish-water Invertebrates of Adyar can survive exposure to air for a longer period than they can remain in freshwater Exception should, however, be made of the species that have a wide range of regional distribution from the sea to almost freshwater This fact explains the predominance of the amphibious element in the fauna of the brackish-waters of the type described here In many terrestrial species life under water is impossible even though these species may be found only in the damp zone just above the water edge Many of the amphibious forms like *Clibanarius padavensis* and *Clibanarius olivaceous* cannot thrive under water for long periods The result is that these species have to keep moving to and fro so as to remain at the water edge when changes in level take place by tidal action It would appear from numerous examples that in brackish-water animals, the tendency to become terrestrial is more marked than that to become freshwater inhabitants Our observations are in agreement with the suggestion made by Pearse (1929) that the number of animals which have reached the land from the littoral marine and from brackish-water is much higher than the number of species that have become fluviatile

The brackish-water areas of the Indian coasts are subject to periodical desiccation in the summer, and the problem of survival during the period of drought is another important factor that the brackish-water animals have to cope with It is the amphibious and the attached animals which are affected by drought For the first group, which consists mostly of burrowers, it is difficult to leave their original burrows and migrate downwards, but this is actually done by several crabs like *Uca annulipes* and *Sesarma quadratum* Species of *Clibanarius*, *Ocypoda cordimana* and *Scylla* *serrata* exhibit what may be called migratory movements in response to seasonal changes During summer, these species are practically absent from the fringes of the backwater, but congregate in large numbers on the southern bank of the river Most of the attached forms like *Campanularia noliformis*, *Laomedea spinulosa*, *Balanus amphitrite*, *Hydroides norvegica* and *Aiptasiomorpha* sp perish during the summer, but fresh individuals settle down every year when the bar is open The periodic inactivity or æstivating habit of the two Grapsoid crabs *Varuna litterata* and *Sesarma tetragonum* has been described by Hora (1933), of these, the former is extremely rare at Adyar during the summer, but *S tetragonum* which occurs in large numbers in the banks of the backwater and the Cooum, behaves in the same manner as in the Gangetic Delta described by Hora We may add to this list another species, *Sesarma quadratum* which also retires into the burrows during the summer and remains more or less inactive It may also be mentioned here that none of the burrowing crabs has been observed to breed during the summer months The Gastropod *Potamides cingulatus* is capable of surviving exposure to air and sunlight for long periods, and specimens have on several occasions been collected far away from the water in an inactive state but which become active again on removal to water The anemone *Phytocœtes gangeticus* remains alive in the mud outside water for weeks together, the anemones do not perish so long as the mud remains a little moist (Panikkar, 1937) Many sedentary brackish-water organisms are known to have evolved peculiar methods of asexual reproduction, reminding one of the gemmule formation of the freshwater sponges, whereby the survival of the species is ensured, the well-known instances are Hydroid *Annulella gemmata* (Ritchie, 1915), the sponge *Laxosuberites lacustris* (Annandale, 1915 *a*), and the Polyzoan *Loxosomatoides lævis* (Annandale, 1915 *b* and 1922) None of these species has so far been observed here, and perhaps the only instance of active asexual reproduction is that of a sea anemone *Boloceractis gopalai* where there is a peculiar method of tentacular regeneration (Panikkar, 1937 *a*) This cannot, however, be considered as having any bearing on the habitat as similar features have been noticed also in a related marine genus

Abbreviation of Life-History.—The disadvantages of the free-swimming ciliated larvae in the brackish and fresh-waters have already been pointed out The changes in reproductive habits consequent upon marine animals taking to a brackish-water mode of life are interesting as they involve curtailment of life-history in several of the species, especially the invertebrates This is very well illustrated by the life-histories of certain brackish-water Polychætes *Marphysa gravelyi* (Aiyar, 1931) and *Diopatra variabilis*

(Krishnan, 1936) have been studied in detail from Adyar, in both the species an abbreviated development has been observed by the above authors In the first, the eggs are laid in large gelatinous egg cases anchored to the worm-burrows and harbouring thousands of eggs in various stages of development, the jelly serving the three-fold purpose of preventing the larvæ from being washed into the sea, of protecting them from drought when they are exposed during low tide, and of catering nutriment to the large number of rapidly developing nectochæts The richly yolk-laden gigantic eggs of *Diopatra variabilis** metamorphose into the young worms even in the tube itself, without the intervention of a free swimming larva The development of this species is characterised both by precocity and by increased provision of food yolk in the eggs as compared to the other species of the same genus, and the developmental differences of very closely allied species could only be explained on the basis of the differences in environmental conditions Gigantic eggs are also found in *Lumbriconereis* sp, also a genus in which Fewkes (1883-85) observed an abbreviated development. The collection of eggs in gelatinous egg-masses is a feature common to most of the Gastropods noticed at Adyar and to certain other species of Polychætes like *Scoloplos* sp Among the Gastropods there is no doubt a free-swimming stage in the life-history, but this phase is often extremely short Interesting details of an extremely short larval stage and rapid metamorphosis have been observed by Rao in the Nudibranch (Ascoglossa) *Stiliger gopalai* † Most of the species of fish that breed at Adyar have demersal eggs, and though specimens of Clupeid and other groups of fish are commonly caught in the brackish-water as the list of animals collected by us would show, none of them breed in the brackish-water ‡

High Rate of Reproduction —Apart from the modifications in development and the asexual reproductive devices, there is another aspect which has not received the proper attention it deserves This is the high intensity of reproductive activity of many of the species As in most tropical animals (*cf* Orton, 1920) many species found at Adyar would appear to be able to breed all through the year, though a well-marked season for breeding is noticeable in many of them in as much as a high rate of reproduction is noticeable during this period As pointed out before, this season is determined by the optimum environmental conditions for any particular species

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* Fauvel (1931) considers the species as being synonymous with *Diopatra neapolitana*

† "Habits, Structure and Early Development of a New Species of *Stiliger*," by K V Rao (1937), unpublished

‡ *Engraulis purava* is a possible exception, *vide* Raj, 1916.

The high rate of sexual propagation accounts for the high intensity of population of animal communities in certain biotopes. The animal communities also often prove the correctness of Thienemann's rule. Most of the species attain sexual maturity at a very small size, well-developed sex-cells are observed in very small individuals of *Potamides cingulatus*, *Sesarma quadratum*, *Acentrogobius neilli*, *Clibanarius olivaceous*, *Metasesarma rousseaxii* and *Meretrix casta*. Rao (*op. cit.*) finds that in *Stiliger gopalai*, sexual maturity is attained within a very short time after metamorphosis and several generations of these Gastropods are produced with singular rapidity. In the Anemone *Phytocœtes gangeticus* where the early development up to the Edwardsia stage is rapid, the post-Edwardsia stages are rather prolonged and the gonads develop even in the larval Edwardsia stages with the incomplete quota of mesenteries. This instance of probable neoteny is further confirmed by the presence of blastula-like stages in the cœlenteron of post-larval individuals. It is probable that the brackish-water habitat may, in some measure, be responsible for this capacity for juvenile reproduction (Panikkar, 1937). Almost every species of invertebrate from Adyar investigated so far, has shown a definite tendency towards early sexual maturity and rapid development, and other reproductive changes like the assumption of hermaphroditism have been observed in the Polychæte *Lycastis indica* (Aiyar, 1935).

Classification of Faunistic Elements.—A convenient basis of classification of animals living in an environment of variable features as the brackish-water is necessary to estimate the exact ecological characters of the different species. Based on the chlorine content of the water, Redeke (1922 and 1931) suggested a division of the brackish-water species into oligohaline, mesohaline and polyhaline groups, the first representing the least saline region (salinity 0·2–1·9 per cent., Cl, 0·1–1·0 gm. per litre) adjoining the freshwater, the second mesohaline region forming the middle zone (salinity 1·9–18·6 per cent., Cl, 1·0–10·0 gm. per litre), and the last polyhaline region merging into the sea-water (salinity 18·6–31·8 per cent., Cl, 10·0–17·0 gm. per litre). He pointed out that these differences in the chlorine content correspond exactly to the differences in the fauna, irrespective of the type of brackish-water investigated. However much this classification may be satisfactory when applied to large volumes of brackish-water like the Baltic Sea, the Black Sea, the Chilka Lake, etc., this division ceases to have any value for small bodies of water as suggested by Redeke himself, and as conclusively shown by Nicol (1935) for salt marsh pools. At Adyar, the grouping of animals according to Redeke's method is not at all applicable since every sudden outbreak of rain in the locality would, especially when the bar is closed, result in quick changes from polyhaline to oligohaline or almost lacustrine conditions, and the most interesting feature of the fauna is the singular capacity of several species to thrive in environments liable to profound changes in salinity and temperature Many of the burrowing invertebrates adjust to salinity changes by vertical migrations (*cf* Panikkar, 1936) So far as our observations go, we have not found strict demarcation of animal communities exclusively on salinity basis At Adyar, the distribution of species is controlled by a multiplicity of factors as the substratum, depth, current of water, vegetation, etc

Fauna of Adyar and of other Regions Compared.—Comparing the fauna of the brackish-waters of Madras with that of the Gangetic Delta and the Chilka Lake, it is clear that though the area is small and without the facilities for admixture of salt and freshwaters on a large scale, the fauna is as representative and almost as rich as in the two other places, especially in regard to true brackish-water species The main difference lies in the fact that in the Chilka Lake and the Gangetic Delta, there are many species from the sea, which at Madras are exclusively marine in habits and are not found in the brackish-water The species of *Philyra*, *Pleurobrachia bengalensis*, *Membranipora* sp , *Alcyonidium mytili*, *Thalassema* sp , *Squilla scorpio*, *Squilla interrupta* and *Lucifer hanseni*, to mention but a few examples, have not so far been observed at Adyar, though they are common in the Madras Coast, and in the brackish-waters of the Chilka Lake and the Gangetic Delta The reason for this is that owing to the absence of a proper gradation of salinities, the small size of the area involved, and the pollution of water as the backwater is situated in the city, only the more resistant of the euryhaline species seem to have secured a foot-hold in the Madras brackish-waters Also, we do not find here a relict fauna as found in the Gangetic Delta represented by recent marine forms that no longer occur in stenohaline or euryhaline conditions, but only in fresh or slightly brackish-water The general features of the fauna described here are in agreement with those of the fauna of the Gangetic Delta and the Chilka Lake, but the constituent elements of the fauna present distinctive features in the occurrence of several characteristic species amongst the invertebrates, especially the Anemones and the Polychætes The proper evaluation of the fauna would, however, be possible only after exhaustive studies have been made of the fauna of the numerous other brackish-water tracts of India

Summary

The fauna of the brackish-waters of the city of Madras has been studied in detail with special reference to its relation with the habitat

The environmental conditions are described in detail About ninety-two species of Invertebrates and fifty-six species of Vertebrates have been observed in the brackish-water The fauna is predominantly marine and includes representatives of all major marine Invertebrate phyla except the Echinodermata The freshwater species include a few Crustaceans, Molluscs and fish The amphibious element in the fauna is well marked, and a number of mud-burrowing species are noted Vertical and regional distribution of the organisms is described and the groups into which they may be classified according to their habits are indicated An account of the breeding in brackish-water species is given The general problems concerning the biology of animal life in the brackish-water are discussed in detail with special reference to the fauna described

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EXPLANATION OF FIGURES

PLATE XVIII.

Photographs of the Adyar backwater and the river, taken during March 1935 The first is a portion of the backwater between the Adyar cemetery and the sand bank, showing the marginal and middle zones The second photograph shows the Adyar river after the Elphinstone Bridge Much of the river-bed is exposed owing to drought

PLATE XIX

(1) Northern bank of the river above the Elphinstone Bridge

(2) Inner reaches of the river showing pools of fresh or slightly brackish-water

PLATE XX.

(1) The river after Elphinstone Bridge to show the deep channel on the southern side

(2) Part of the Adyar backwater near the small bridge close to the cemetery

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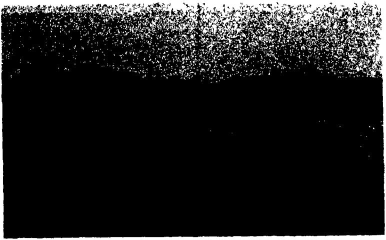
and R. Gopala Aiyar



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N. Kesava Panikkar
and R. Gopala Aiyar

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TEXT-FIG 1

Map of the Adyar river and backwater to illustrate the different regions surveyed in this study

IG 2

Imaginary section through a mud-flat on the side of the backwater to show the approximate zonation of animals, especially the burrowing species Numbers 1 26 represent the following species —

1 *Pontodrilus bermudensis*
2 *Ocypoda cordimana*
3 *Ocypoda macrocera*
4 *Sesarma tetragonum*
5 *Varuna litterata*
6 *Metaplax distincta*
7 *Uca annulipes*
8 Zone of *Lycastis indica*
9 *Lumbriconereis* sp
10 *Phytocœtes gangeticus*
11 *Sesarma quadratum*
12 *Boleophthalmus boddœrti*
13 *Periophthalmus pearsei* and *P kœlreutri*
14 *Clibanarius olivaceous*
15 *Potamides cingulatus*
16 *Phytocœteopsis ramunni*
17 *Pygmœonassa orissœnsis*
18 *Clibanarius padavensis*
19 *Scylla serrata*
20 *Stephensonactis ornata*
21 *Pelocœtes exul*
22 *Meretrix casta*
23 *Neptunus pelagicus*
24 *Neptunus sanguinolentus*
25 *Marphysa gravelyi*
26 *Diopatra variabilis*

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THE MYXOPHYCEAE OF THE UNITED PROVINCES, INDIA.—III.*

By C Bhashyakarla Rao, M Sc

(Research Scholar in Botany, Benares Hindu University)

Received June 25, 1937.

[Communicated by Prof. Y Bhāradwāja, M Sc, Ph D (Lond), F L S]

THE present communication is the third[1,2] of the series, 'The Myxophyceæ of the United Provinces, India'. It deals with algæ (hitherto unrecorded with the exception of *Anabæna ambigua* Rao) collected mainly from Benares and its environs from 1934 onwards. A few forms collected from Chakia, Chunar, Saranath, Ramnagar and Mussoorie have also been included. In all there are one hundred and five forms, representing twenty-five genera, and out of these, two species, sixteen varieties and twenty-seven forms are new. The habitat of these plants is varied; thirty-five have been collected on soil, seven from moist bricks, stones and rocks, eleven on walls and other elevated places, four on the bark of trees, five from the stagnant water of crop-fields and the rest from tanks, ponds, puddles and other aquatic situations.

The major part of the Benares Myxophyceæ are sub-aerial in habitat. After the rains, one comes across very frequently on semi-clayey soil, during July and August, a very thick, semi-transparent and ash-brown mucilaginous scum extending over large areas and making the ground slimy. This is mostly comprised of *Aphanothece pallida*. It may be intermingled with *Chroococcus montanus* forma and var *hyalina*, *Aphanocapsa Grevillei*, *Microcoleus chthonoplastes* and others. On clayey soil, however, the stratum formed is deep blue-green and slimy, but closely adhering to the surface. This is commonly comprised of *Glœocapsa stegophila* var *crassa*, *Cylindrospermum muscicola*, *Microcoleus chthonoplastes* and *M sociatus*. During July and August, *Cylindrospermum muscicola* is noticed very frequently to form by itself blue-green strata on moist soil, and as its spores ripen the strata turn blackish-brown. In the month of September, conspicuous blue-green erect tufts of a form of *Symploca muralis* appear on shady soil. Frequently during August and September, circular, woolly, slimy and brown patches are seen scattered on the surface of lawns. These expand and finally coalesce to produce a brownish green stratum which for the most part consists of *Microchæte tenera*, *Scytonema javanicum*, with which, however, *Microcoleus chthonoplastes* and a form of *Anabæna variabilis* may be intermingled. *Oscillatoria terebriformis* is the most common species of *Oscillatoria* in Benares and it occurs not only on all exposed muddy places, but also in stagnant ponds, puddles and dirty drains. *Oscillatoria formosa* is another form commonly met with in Benares, especially during rains, forming a a crimson-green layer on the soil of shallow puddles and ditches. Among the other common blue-green algæ, occurring on moist soil, mention may be made of *Oscillatoria sancta*, *Phormidium Retzii* and *Lyngbya ceylanica*. On places which are constantly wet, because of their being near drains or other water sources, *Phormidium subtruncatum* is very common. This alga has also been found growing in very delicate blue-green films spread on the sides of the aspirator bottles kept out of use in the Laboratory. *Scytonema ocellatum*, *Lyngbya truncicola*, *L. æstuarii* var *arbustiva* and *L. arboricola* are seen after rains in the form of expanded bluish-green woolly layers on the bark of *Mangifera indica*, *Eugenia Jambolana*, *Bassia latifolia* and *Tamarindus indica*. As the season becomes drier, the strata formed by these algæ become thin and papery, and may ultimately peel off the trunk of the tree.

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* From the Department of Botany, Benares Hindu University.

[1] Bhāradwāja, Yajnavalkya, "The Myxophyceæ of the United Provinces, India—I," *Proc. Ind. Acad. Sci.*, 1935, **2**, No 1, Sec. B.

[2] Bhashyakarla Rao, C., "The Myxophyceæ of the United Provinces, India—II," *Proc. Ind. Acad. Sci.*, 1936, **3**, No. 2, Sec. B.

In Benares, there is a comparative paucity of the real aquatic forms. This is due to the fact that there are no large and permanent sheets of stagnant water. The characteristic aquatic habitats of these algæ are a large number of pools, puddles and ditches formed by the stagnant rain-water in low-lying areas either in waste-places or amidst crop-fields or on the sides of the River Ganges, which flows by the side of the town. Some of the common planktonic forms are *Microcystis flos-aquæ*, *Chroococcus turgidus*, *C. minutus*, *Merismopedia tenuissima* and *Spirulina platensis* var *crassa*. *Oscillatoria princeps* is rather frequent near the edges of pools, puddles and ditches as black masses of densely crowded hair-like filaments. Species of *Anabæna*, such as *A. aphanizomenoides* var *ellipsospora*, *A. Iyengari* var *tenuis*, and *A. unispora* var *crassa*, occur in a large number of rain-water pools. They are sterile during July and August, but form spores in September and October. *Glœotrichia natans* occurs as large blue-green globules attached to aquatic angiosperms. *Glœotrichia intermedia* var *kanwænse* is abundant in several rain-water pools, either in a free state or adhering to *Chara*, and other aquatic plants. *Aulosira fertilissima* var *tenuis* and *Phormidium mucosum* var *arvense* are found in abundance during rains in stagnant water of crop-fields. *Lyngbya confervoides* grows in thick fibrous and deep blue-green masses in the shade of closely spreading leaves of ***Nelumbium*** in the ornamental water reservoirs.

The Benares Myxophyceæ grow luxuriantly during the rainy months of July, August and September and to some extent in October and November. But they are quite scarce during May and June, when it is very hot and dry. Some of the forms available during these hot months are ***Microcystis flos-aquæ***, ***Merismopedia tenuissima*** and *Spirulina major*, occurring in tanks with constant water supply, and also *Oscillatoria terebriformis* and ***Phormidium subtruncatum*** inhabiting places near water.

SYSTEMATIC ENUMERATION OF THE SPECIES OBSERVED

I CHROOCOCCALES

Chroococcaceæ

Genus *Microcystis* Kutzing

1 *Microcystis æruginosa* Kützing Geitler, in Rabenhorst's *Kryptogamenflora von Europa*, Band XIV, Cyanophyceæ, 1930 32, p 136, Fig 59 *d*, Frémy "Les Myxophycées de Madagascar," *Annales de Cryptogamie exotique*, t III, fasc IV, 1930, Pl IV, Fig 5, Crow, "The taxonomy and variation of the genus *Microcystis* in Ceylon," *New Phytologist*, 1923, Vol 22, No 2, Pl I, Fig *a*, Tilden, *Minnesota Algæ*, Vol I, 1910, Pl II, Figs 21 and 22

Var *elongata* var nov (Fig 1, *A–C*)

Colonies spherical or elongated, solid or broken through to form a net, broken parts of the colony looking like filaments, sheath indistinct, stained violet with methylene blue, cells pale blue-green, more or less spherical, with gas-vacuoles.

Lat cell, 2–2 8 μ

Habitat —In an ornamental water reservoir of a private garden, along with *Oscillatoria Annæ*, *Lyngbya limnetica* and *Oedogonium* sp.

The form agrees with the type in having spherical or elongated colonies, which are solid or broken through with an indistinct sheath, and spherical cells with gas-vacuoles, but differs in the cells being smaller and the broken portions of the colonies looking like filaments.

Genus *Aphanocapsa* Nægeli

2 *Aphanocapsa Koordersi* Strøm Geitler, *op cit*, 1930–32, p 155, Fig 68

Colonies without definite shape. Cells laxly crowded, circular to subglobose with pale blue-green homogeneous contents

Lat cell, 2 2–3 2 μ

Habitat:—In the fountain tank, Women's Hostel, Benares Hindu University, along with *Synechocystis aquatilis* and *Oedogonium* sp (Miss P. R Parukutty Amma)

3 *Aphanocapsa Grevillei* (Hass) Rabenh Geitler, *op. cit*, 1930–32, p 158, Fig 71, Frémy, "Les Myxophycées de l'Afrique équatoriale française," *Arch d Bot*, iii (1929), Mem 2, 1930, p 23, Fig 25, Tilden, *op cit*, 1910, Pl II, Fig 7, West, *Algæ*, I, 1916, p 3, Fig 2, *A*

Lat cell, 3·2–4 8 μ

Habitat —On the sides of the steps of a tank along with other algæ

The plant-mass occurs as small yellowish patches distributed irregularly

4 *Aphanocapsa pulchra* (Kütz) Rabenh Geitler, *op cit*, 1930–32, p 156, Fig 69 *g*, Frémy, *op cit*, 1930, p 23, Fig 22

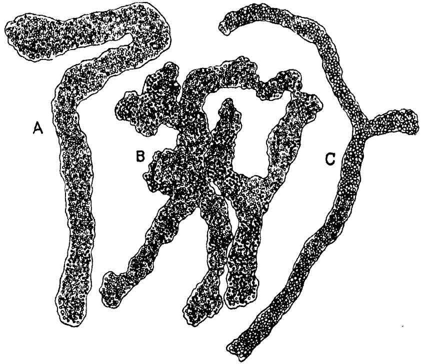


FIG 1. *A–C—Microcystis aeruginosa* Kütz. var *elongata* var. nov.

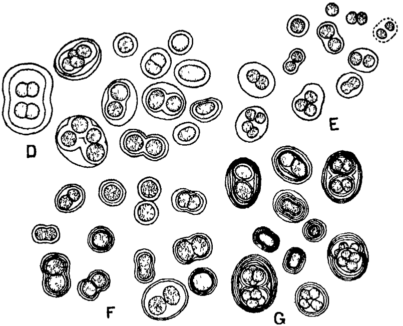


FIG 1 *D—Glœocapsa stegophila* (Itzigs) Rabenh var. *crassa* var nov , *E—Chroococcus minimus* (Keissl) Lemm , *F & G—Chroococcus montanus* Hansg forma and var *hyalina* var nov respectively

A-C & G × 425 , *D & F* × 875 , *E* × 1,475

Lat cell , 3 2–4 5 μ

Habitat —Planktonic in a tank, Cantonment area

Genus *Aphanothece* Nægeli

5 *Aphanothece bullosa* (Menegh) Rabenh Frémy, *op cit* , 1930, p 33, Fig 33

Lat cell , 4·9–5·4 μ , long cell , 6 6-13 2 μ

Habitat —Free-floating in a rain-water pool along with *Lyngbya spiralis* Geitler

The stratum is a deep blue-green fragile mass

Genus *Glœocapsa* Kützing

6 *Glœocapsa punctata* Näg Frémy, "Les Myxophycées de Madagascar," *Annales de Cryptogamie exotique*, t iii, fasc IV, 1930, Pl V, Fig 19, Geitler, *op. cit* , 1930–32, p. 189

Lat cell, 1 6–3 μ, long cell, 3 2 μ, lat cell cum vag, 3 5–4 μ, long cell cum vag, 4·2–6 μ

Habitat —In a cemented water-reservoir of a private garden, along with *Nostoc spongiæforme* var *tenuis*, *Tolypothrix lanata* forma, *T distorta* var *samoënsis* and *Oedogonium* sp

7 *Glœocapsa stegophila* (Itzigs) Rabenh Geitler, *op cit*, 1930–32, p 197, Fig 91 *b*, Tilden, *op cit*, 1910, Pl I, Fig 24

Var *crassa* var nov (Fig 1, *D*)

Thallus soft, yellowish-brown, cells spherical, sub-spherical or elongated, commonly single or in colonies of 2 4, sheath golden yellow, sometimes striated

Lat cell, 4 6 4 μ, long cell, 6 4–9 6 μ, lat colon cum vag, 8 15 μ, long colon cum vag 9 6–19 2 μ, crass vag, upto 3·2 μ

Habitat —On moist soil, singly or along with *Microcoleus chthonoplastes*, *M sociatus*, *Cylindrospermum muscicola* and others

The variety differs from the type in having bigger cells and colonies

Genus *Chroococcus* Naegeli

8 *Chroococcus turgidus* (Kutz) Näg Geitler, *op cit*, 1930–32, p 228, Fig 109 *b*, Frémy, *op cit*, 1930, p 41, Fig 40, Tilden, *op cit*, 1910, Pl I, Fig 3, West, *op cit*, 1916, p 41, Fig 25 *b*

Lat. cell, 11 5 16 5 μ, long cell, 16 5 μ, lat cell cum vag, 14–19 2 μ, long cell cum vag 19 5 μ, lat colon cum vag, 16 5–21 2 μ, long colon cum vag, 21 4–23 1 μ

Habitat —Planktonic in the tank of the Benares Electric Light and Power Supply Co, Ltd, along with *Chroococcus minutus*, *Merismopedia tenuissima* and *Spirulina major*

The cells are yellowish-green, mostly 2–4 in each colony

9 *Chroococcus minutus* (Kütz) Näg Geitler, *op cit*, 1930–32, p 234, Fig 113 *c*, Frémy, *op cit*, 1930, p 41, Fig 42

Lat cell, 5–6 6 μ; long cell, 3 3–6 μ, lat cell cum vag, 6 0–10 μ, long cell cum vag, 6 3–13 μ, lat colon cum vag, 6 6–10 μ, long colon cum vag, 6 6–15 5 μ

Habitat —Planktonic in the tank of the Benares Electric Light and Power Supply Co, Ltd, along with *Chroococcus turgidus*, *Merismopedia tenuissima* and *Spirulina major*

Cells are mostly in colonies of two and rarely four.

10 *Chroococcus minimus* (Keissl) Lemm Lemmermann, *Kryptogamenflora d Mark Brandenburg*, iii, Algen I, 1910, p 59, Geitler, *op cit*, 1930–32, p 233 (Fig 1, *E*)

Lat cell, 1 6–2 5(–3) μ, long cell, 2–3 2 μ, lat cell cum vag, 3–4 5 μ, long cell cum vag, 3 2–5 μ, lat colon cum vag, 4 8–6 4 μ long colon cum vag, 4 8–8 4 (–9 6) μ

Habitat —In an ornamental tank of a private garden, on the sides of a cemented water reservoir, by the side of the road leading to Allahabad

The sheath in the form collected from the ornamental tank is sometimes dissolved or very indistinct

11 *Chroococcus varius* A Braun Geitler, *op cit*, 1930–32, p 235, Fig 114 *a*

Lat cell, 2–4 μ, long cell, 2 5–4 μ, lat cell cum vag, 3 5 μ, long cell cum vag, 3 5–5 μ, lat colon cum vag, 4 2 8 4 μ, long colon cum vag, 4 5–11 6 μ

Habitat —On the cemented platform of the Physical Laboratory, College of Science, Benares Hindu University

12 *Chroococcus montanus* Hansg Geitler, *op cit*, 1930–32, p 236

Forma (Fig 1, *F*)

Lat cell, 5 6 4 μ, long cell, 4 8–8 μ, lat cell cum vag, 6 4–9 6 (12 8) μ, long cell cum vag, 8–11 2 μ, lat colon cum vag, 8 8–16 μ, long colon cum vag, 11 2–14 4 μ

Habitat —On moist soil, along with *Microcoleus chthonoplastes* and others

The form differs from the type in the sheath being hyaline

Var *hyalina* var nov (Fig 1, *G*)

Stratum thick, mucilaginous and blue-green Cells spherical or subspherical or elongated, single or 2–4 or occasionally upto 8 in spherical or ellipsoidal colonies Colonies separate Sheath thick, hyaline and lamellated

Lat cell, 4 8–7 5 μ, long cell, 8–16 5 μ, lat cell cum vag, 13 2–23 1 μ, long cell cum vag, 13 2–30 μ, lat colon cum vag, 19 8–26 μ, long colon cum vag, 19–36 μ

Habitat —On moist soil along with other algæ

The variety agrees with the type in the mucilaginous stratum, the presence of 2–4 or occasionally more cells in each colony, and the sheath enveloping the colonies being stratified, but it differs from the same in the stratum being blue-green and the colonies, which are on the average bigger, possessing a hyaline and thick sheath

13. *Chroococcus pallidus* Näg Geitler, *op cit*, 1930–32, p 238, Fig 116 *b*, Frémy, *op cit*, 1930, p 41, Fig 48

Lat cell, 4 8–6 6 μ, long cell, 4 8–7 μ, lat cell cum vag, 6·6–10 μ, long cell cum vag, 6 6–11 6 μ, lat colon cum vag, 8 4–10 5 μ, long colon cum vag, 10 5–13 2 μ

Habitat —On wet soil along with *Cylindrospermum muscicola*, *Microcoleus chthonoplastes* and others

The cell-contents are deep blue-green

Genus *Merismopedia* Meyen

14 *Merismopedia minima* G Beck Geitler, *op cit*, 1930–32, p 263, Bhashyakarla Rao, "The Myxophyceæ of the United Provinces, India—II," *Proceedings of the Indian Academy of Sciences*, 1936, Vol III, Sec B, p 166, Fig 1, *B*

Forma

Lat cell, 0 2–0 4 μ

Habitat —Planktonic in the fountain tank, College of Science, Benares Hindu University

The form differs from the type in possessing smaller cells and colonies consisting of upto 320 cells

15 *Merismopedia tenuissima* Lemm Geitler, *op cit*, 1930–32, p 264, Fig 129 *b*, Frémy, "Les Cyanophycées des Côtes d'Europe," *Mémoires de la Société Nationale des Sciences Naturelles et Mathématiques de Cherbourg, tome* XLI, 1934, Pl I, Fig 1, Geitler, in Pascher's *Susswasserflora Deutschlands, Osterreichs und der Schweiz*, Heft 12, Cyanophyceæ, 1925, p 107, Fig 123 *a*

Lat cell, 1 6–2 μ

Habitat —Planktonic in the tank of the Benares Electric Light and Power Supply Co, Ltd, along with *Chroococcus turgidus*, *C minutus* and *Spirulina major*.

The colonies are generally of 16–48 cells

Genus *Synechocystis* Sauvageau

16 *Synechocystis aquatilis* Sauvageau Tilden, *op. cit*, 1910, Pl I, Fig 10 (Fig 2, *A*)

Lat cell, 5 6–6 5 μ

Habitat —In the fountain tank, Women's Hostel, Benares Hindu University, along with *Aphanocapsa Koordersii* and *Oedogonium* sp (Miss P R Parukutty Amma), in a temple tank, Benares City

Genus *Dactylococcopsis* Hansg

17. *Dactylococcopsis raphidioides* Hansg Geitler, *op cit*, 1930–32, p 281, Fig 137, Printz, "Sub-aerial Algæ from South Africa," *Norske Videnskabers selaskabs skrifter*, 1920, No 1, Pl 11, Figs 328-36, Borge, Beitrage zur algenflora von Schweden," *Arkiv for Botanik*, Band 18, No 10, Pl I, Fig 1

Forma.

Lat cell, 1 6–2 μ, long cell, 20–35 (– 40) μ

Habitat —In a pond on the University grounds, along with *Calothrix marchica* var *intermedia*, *Anabæna fertilissima* sp nov, *A Iyengari* var *tenuis*, *Oscillatoria animalis*, *Lyngbya Digeuti* forma and sterile filaments of *Spirogyra* and *Oedogonium*

The form differs from the type in the cells being longer and usually falciformed It also differs from forma *falciformis* Printz in having much longer cells

II CHÆMOSIPHONALES

Chæmosiphonaceæ

Genus *Chæmosiphon* A Braun et Grunow

18 *Chæmosiphon sideriphilus* Starmach Geitler, *op cit*, 1930-32, p 431, Fig 251

Var *glabra* var nov (Fig 2, *B*)

Sporangia distributed on the host either singly or in dense clusters, usually club-shaped, rarely cylindrical, bent or straight, pale blue-green with homogeneous contents Sheath thin, hyaline and smooth Exospore one

Lat sporang, 2·4–3 2 (– 4) μ, long sporang, 4–14 4 μ, lat sporang cum vag, 3 2–3 5 μ, long sporang cum vag, 4 8–17 6 μ

Habitat —On *Lyngbya gracilis* in the reserve water tank of the Benares Water Works

The variety agrees with the type in the possession of club-shaped or cylindrical sporangia with one exospore and a foot formed by the enveloping sheath, but differs in the sporangia possessing much shorter range of dimensions and the sheath being always smooth, hyaline and without any calcareous impregnation

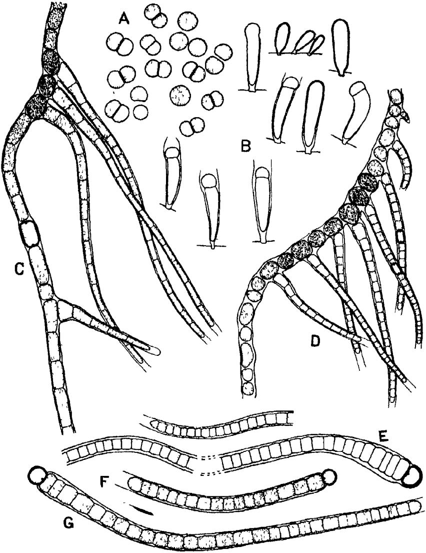


FIG. 2 *A—Synechocystis aquatilis* Sauvageau; *B—Chæmosiphon siderophilus* Starmach var *glabra* var nov.; *C & D—Hapalosiphon Welwitschii* W. et G. S West *forma*, *E*—Portions of the filament of *Calothrix marchica* (Lemm) var *crassa* var nov; *F & G—Calothrix marchica*, Lemm. var. *intermedia* var nov.

B × 1,475, all the rest × 875

III HORMOGONEALES

1 Stigonemataceæ

Genus *Hapalosiphon* Naegeli

19. ***Hapalosiphon Welwitschii*** W et G S West Geitler, *op cit*, 1930–32, p 530, Fig 328 *a*

Forma (Fig 2, *C* and *D*)

Plant-mass dark green, filaments closely entangled Sheath thin, firm and hyaline Cells spherical, quadratic or longer than broad Branches short and narrower than the main axes Heterocysts rare, long-cylindrical Spores more or less spherical or longer than broad

Main axis Lat cell, 3–7 5, rarely 9 μ, long cell, 4 5-15, rarely 16 8 μ Branches lat cell, 3–6 μ, the basal cell being 7 5 μ, long cell, 2 2–16 5 μ Lat het, 4 5 7 μ, long het, 7 5–10 μ, lat spor, 6–12 μ, long spor, 5 2-12 5 μ, crass vag, 0 2 μ

Habitat —Closely adhering to the moist bricks at the edge of a rain-water pool

The form differs from the type in the terrestrial habitat and in the filaments being closely entangled

2 Rivulariaceæ

Genus *Calothrix* Agardh

20 ***Calothrix marchica*** Lemm Geitler, *op cit*, 1930 32, p 607, Fig 382 *a*

Var *crassa* var nov (Fig 2, *E*)

Filaments in groups, irregularly bent and closely entangled Sheath thin, firm, yellowish or hyaline Trichomes with constrictions at septa, with tapering ends but without any hair-like prolongation, end-cell conical with a rounded apex, sometimes pointed Cells quadratic, as well as shorter or longer than broad Heterocysts single, basal, spherical or sub-spherical

Lat fil, 9 6–14 4 μ, long trich, upto 450 μ, lat trich, 8 4–12 8 μ, long cell, 2–3 2 μ, at top 4 8 μ, lat het, 8 2-12·5 μ, long het, upto 5 μ

Habitat —On the plinth of the College building, near the outlet of a drain, along with *Calothrix linearis* forma

The variety agrees with the type in (1) the tapering trichomes without any hair-like prolongation, (2) the barrel-shaped cells, (3) the rounded or sometimes pointed end-cells and (4) the single spherical or sub-spherical basal heterocysts, but it differs in the broader, irregularly bent and closely entangled filaments, arranged in groups, in the much broader trichomes and heterocysts, and in the yellow sheath

Var *intermedia* var nov (Fig. 2, *F* and *G*)

Filaments epiphytic on other algæ, placed singly or in groups of two or three, with slight attenuation, without the formation of a terminal hair Sheath thin, firm and hyaline Cells quadratic, as well as shorter or longer than broad, with constrictions at the joints, end-cell rounded Heterocysts single, basal and usually spherical

Lat fil, 6–8 μ, long trich, upto 350 μ, lat trich, 5 8–7 8 μ, long cell, 3·2–8 μ, lat het, 5 6–7·8 μ

Habitat —In a pond on the University grounds, along with *Dactylococcopsis raphidioides* forma, *Anabæna fertilissima* sp nov, *A Iyengari* var *tenuis*, *Oscillatoria animalis*, *Lyngbya Digeuti* forma and sterile filaments of *Spirogyra* and *Oedogonium*

This form comes close to *Calothrix atricha* Frémy (Frémy, *op cit*, 1930, p 263, Fig 233) which Geitler (*op cit*, p 625) considers to be identical with *Calothrix marchica* Lemmermann It resembles *Calothrix marchica* Lemm in the free filaments, the absence of a hair-like prolongation at the ends of the trichomes, the constrictions at the joints, the thin and hyaline sheath, and in the single, spherical or sub-spherical basal heterocysts But it differs from this form in the trichomes possessing only slight attenuation, in the rounded end-cell and in the bigger dimensions of all parts The dimensions of this form are intermediate between those of the type and the var *crassa*

21 *Calothrix linearis* Gardner Geitler, *op cit*, 1930-32, p 622, Fig 395 *d*

Forma

Lat fil, at base 10–12 μ, at top 4–5 μ, long trich, upto 450 μ; lat trich, at base 6·6–9 5 μ, at top 3–3·3 μ, long cell, 2 5–5 μ, lat het, 6 6–8 μ, long het, 5–7 μ

Habitat —On the plinth of the College building, near the outlet of a drain, along with *Calothrix marchica* var *crassa*

The form differs from the type in the trichomes being broader at the base and the cells in the terminal portions of the trichomes being quadratic or shorter than broad

22 *Calothrix brevissima* G S West "Report on the Fresh-water Algæ, including Phytoplankton of the Third Tanganyika Expedition conducted by

Dr W. A Cunnington, 1904–1905," *Journal of the Linnean Society Bot*, 1907, 38, p 180, Pl 10, Fig 8

Lat fil, 4 8–6·6 μ, long fil, 40–85 μ, lat trich, 3 8–4 5 μ, long cell, 1·6–3·5 μ; lat het, 3 8–4 8 μ, long het, 4–4·5 μ

Habitat :—Epiphytic on *Hydrodictyon reticulatum* growing in a rain-water pool, along with *Spirogyra chuniæ* forma

Genus *Glœotrichia* Agardh

23 *Glœotrichia Raciborskii* Woloszynska Geitler, *op cit*, 1930–32, p 637, Fig 405 *a* and *b*, Geitler, *op cit*, 1925, p 233, Fig 281 *b*

Var *kashiense* var nov (Fig 3, *A*–E)

Thallus forming large irregularly-lobed blue-green masses, 2–10 cm thick Filaments with a thick, stratified and hyaline sheath Trichomes with constrictions at joints, ending in a long hair Cells at the base of the trichome barrel-shaped, much shorter than broad or almost as long as broad, higher up cylindrical, in the hair long cylindrical Heterocysts single, spherical to ellipsoidal Spores long, ellipsoidal to cylindrical with a hyaline smooth outer wall

Lat. trich, at base 8 4–10 μ, higher up 4 8–6 4 μ, at apex 2 4 μ, long. trich, 800–1,000 μ, long cell, at base 2 4 μ, later 3 3–10 μ, in the hair upto 15 μ, at apex upto 35 μ, lat het, 8–12 8 (–13 2) μ; long het, 8 4–15 (–16 5) μ, lat spor, 11 5–16 μ, average 13 2 μ, long spor, 42–66 μ

Habitat .—In a rain-water puddle amidst crop-fields

The variety agrees with the type in all respects except that the former has much bigger thallus, broader trichomes, hyaline sheath, bigger heterocysts, that may be ellipsoidal, and narrower spores of a wider range in length with a hyaline outer wall This form is also comparable to var *Lilienfeldiana* (Wol) Geitler on account of the spherical or ellipsoidal heterocysts and cylindrical spores with a colourless outer wall, but here also it differs in possessing bigger heterocysts and narrower spores

3 Microchætaceæ

Genus *Microchæte* Thuret

24 *Microchæte tenera* Thuret Frémy, *op cit*, 1930, p 281, Fig 248, Tilden, *op cit*, 1910, Pl X, Fig. 11

Lat fil, 5–7·1 μ, lat cell., 4–5 μ, long. cell, 4·8–8 μ; lat. het., 4 5–6·4 μ, long. het, 6 4–10 μ

Habitat :—On wet soil of the lawns, Benares Hindu University

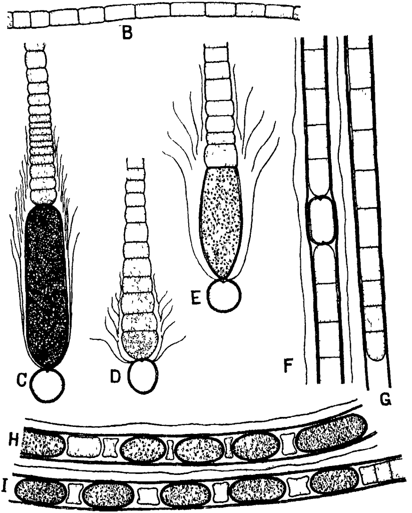


Fig 3 *A*—Terminal, *B*—middle and *C–E*—lower portions of the filament of *Glœotrichia Raciborskii* Woloszynska var. *kashiense* var nov., *F & G*—vegetative and *H & I*—sporogenous portions of the filaments of *Aulosira fertilissima* Ghose var. *tenuis* var. nov. *A–E* × 875 ; *F–I* × 1,475.

Genus *Aulosira* Kirchner

25 *Aulosira Fritschii* Bhâradwâja Bharadwaja, "Contributions to our knowledge of the Myxophyceæ of India," *Annals of Botany*, 47, 185, 1933, p 123–131, Figs 3 and 4

Lat fil, 11·2–16 5 μ, crass vag, upto 3 μ, lat cell, 8 11 8 μ, long cell, 5–26 μ, lat het, 11 2–13 2 μ, long het, 11 8–40 μ, lat spor, 10–13 2 μ, long spor, 6 6 30 μ

Habitat —In a stagnant rain-water puddle, by the side of the B N W Railway line, about 2 miles off Benares Cantonment Station, along with *Lyngbya confervoides*, *Oscillatoria princeps* and several others

26 *Aulosira fertilissima* Ghose Ghose, "A systematic and an ecological account of the blue-green algæ of Lahore and Simla," *Jour Linn Soc Bot*, 46, 1923, Taf 31, Fig 9

Var *tenuis* var nov (Fig 3, *F–I*)

Plant-mass fibrous and greyish blue Filaments free more or less straight and closely crowded together, with a thin, firm and brown sheath, that may sometimes be enveloped by diffluent mucilage Trichomes slightly tapering at the ends, rarely constricted at the septa, end-cell with a rounded apex Cells cylindrical, sometimes quadratic Heterocysts cylindrical, with rounded end-walls broader than the trichome and causing the filament to bulge Spores in long chains, ellipsoidal to cylindrical, intercalated by moribund cells

Lat fil, 5 6 6 4 μ, lat trich, 3 3–4 8 μ, long cell, 3 3–19 8 μ, lat het, 4·5–7 μ, long het, 8 2–19 8 μ, lat spor, 4 8–8 8 μ, long spor, 10 5–19 2 μ, crass vag, 0 3–0 8 μ

Habitat —In the stagnant water of a paddy field

The variety agrees with the type in having (1) cylindrical or quadratic cells, (2) cylindrical heterocysts, (3) ellipsoidal spores in chains and (4) moribund cells in between the spores, but it differs from it in the fibrous stratum, the much narrower trichomes, the narrower heterocysts and the much smaller spores (that are also cylindrical) with a colourless outer wall

4 *Scytonemataceæ*

Genus *Tolypothrix* Küetzing

27 *Tolypothrix nodosa* Bhâradwâja Bharadwaja, "The Taxonomy of *Scytonema* and *Tolypothrix* including some new records and new species from India and Ceylon," *Revue Algalogique*, 1933, n 1–2, p 176, Fig 7c.

Lat fil., 5·4–8 μ, lat trich., 4·8–6·8 μ, at apices 4 μ, long cell., 3·2–12·8 μ; lat het., 4·8–9·6 μ, long het., 6·4–16·8 μ, rarely upto 23 μ.

Habitat.—In rain-water pools.

28. *Tolypothrix lanata* Wartm. Geitler, *op. cit.*, 1930–32, p. 717, Fig. 459 *d*.

Forma

Lat. fil., 8·2–11·2 μ, lat. trich., 6·8·2 μ, long. cell., (5·-) 6·4–10·4 μ, lat. het., 6·6–8·2 μ, long. het., 10·5–16·5 μ.

Habitat.—In a cemented water reservoir in a private garden, along with *Nostoc spongiæforme* var. *tenuis*, *Tolypothrix distorta* var. *samoensis*, *Glæocapsa punctata* and *Oedogonium* sp.

The form differs from the type in having narrower trichomes and in the absence of heterocysts in chains.

29. *Tolypothrix distorta* Kütz. var. *samoensis* Wolle. Bhâradwâja, *op. cit.*, 1933, p. 176, Fig. 7 *b*. Bhâradwâja, "False branching and Sheath-structure in Myxophyceæ, with special reference to the Scytonemataceæ," *Archiv für Protistenkunde*, Band 81, Heft 2, 1933, Fig. 3, *E* and Fig. 4, *G*.

Lat. fil., 14–19·8 μ, when old upto 22 μ, crass. vag., 3·3–4 μ, when old and unhealthy upto 6 μ, lat. trich., 12·2–15 μ, when old narrowed down to 10·2 μ, long. cell., 3·2–12 μ, lat. het., 11·8–13·2 μ, long. het., 10–23 μ.

Habitat.—In a cemented water reservoir in a private garden, along with *Nostoc spongiæforme* var. *tenuis*, *Tolypothrix lanata* forma, *Glæocapsa punctata* and *Oedogonium* sp.

30. *Tolypothrix robusta* Gardner. Geitler, *op. cit.*, 1930–32, p. 715, Fig. 457 *b*.

Forma

Diam. fil., 13–17 μ, when old upto 20 μ, crass. vag., 2·4·5 μ, when old and unhealthy upto 6·6 μ, diam. trich., 9–12 μ, when old and unhealthy narrowed down to 6·6 μ, at growing apices upto 15 μ; long. cell., 10–12 μ; when old and unhealthy upto 30 μ, at growing apices upto 5 μ, lat. het., 10–13·2 μ; long. het., 13–42 μ.

Habitat.—Floating in a stagnant pond.

The form differs from the type in the presence of narrower filaments and trichomes and in the heterocysts being frequently longer and found singly or in chains of 2 to 3.

31. *Tolypothrix fragilis* (Gardner) Geitler Geitler, *op cit*, 1930–32, p 725, Fig 465

Lat. fil, 5·5–7 μ, lat trich, 4·9–6 μ, long cell, 3–5 μ, lat het, 6·6–7 μ; long het, 4–10 μ

Habitat.—On the white-washed wall of the temple at Kanwa, Benares, along with *Lyngbya truncicola* and others

Genus *Scytonema* Agardh

32 *Scytonema coactile* Mont Geitler, *op cit*, 1930–32, p 753, Fig 479 *a–c*

Lat fil, 17–19·8 μ, when old upto 23 μ, crass vag, 2–3 μ, when old upto 4 8 μ, lat trich, 10–15 μ, when old narrowed down to 7 μ, lat het, 13·2–15 μ, long het, 11 8–17 3 μ

Habitat —Free-floating in a tank of a private garden

33 *Scytonema stuposum* (Kütz) Born Frémy, *op cit*, 1930, p 305, Fig 260, Tilden, *op cit*, 1910, Pl XII, Figs 13 and 14

Lat fil, 19 8–23 μ, when old upto 26 μ, crass vag, 2 4 8 μ, when old and unhealthy upto 6 μ, lat trich, 10–14 μ, when old and unhealthy narrowed down to 8 μ, long cell, 3 3–13 2 μ, lat het, 13 2–15 μ, long het, 11 8–19 μ

Habitat.—On clayey soil by the side of the road leading to Saranath

The sheath in this form is yellowish-brown and stratified

34. *Scytonema ocellatum* Lyngbye Frémy, *op cit*, 1930, p 309, Fig 263

Lat fil, 17·6–19 2 μ, when old upto 20 μ, crass vag, 2 4–3 2 μ, when old upto 5 μ, lat trich, 9 6–14·4 μ, when old and unhealthy narrowed down to 8 μ, long cell, 5–14 4 μ, when old and unhealthy upto 19 μ, lat het, 14·4–16 μ, long het, 11 2–16 μ

Habitat —On moist soil in shade, on the bark of *Tamarindus indica* and *Mangifera indica*

35. *Scytonema javanicum* (Kütz) Born Frémy, *op cit*, 1930, p 310, Fig 264, Ghose, "On some Myxophyceæ from Rangoon," *Journal of the Burma Research Society*, Vol XV, Part III, 1926, Pl VII, Fig 18.

Lat fil, 13·2–16·5 μ, when old upto 18 μ, crass vag, 0·9–1 8 μ, when old upto 3·5 μ, lat trich, 11 8–13·2 μ, when old narrowed down to 8 μ; long. cell, 2–11·8 μ, lat het, 11·8–13·2 μ, long het, 10–16 5 μ

Habitat:—On shaded soil at the edge of a rain-water pool

36 *Scytonema guyanense* (Mont) Born et Flah Frémy, *op. cit*, 1930, p 312, Fig. 265

Lat fil, (13·2–) 15–16·5 μ, when old upto 20 μ, crass vag, 2–3 μ, when old upto 4 μ, at apices thinned out to 1 μ, lat cell, 11–14 μ, when old narrowed down to 9 μ, long cell, 4·8–19·8 μ, lat. het, 10–14 μ, long het, 13–20 μ

Habitat —On moist rocks, among liverworts and mosses, Mussoorie

37 *Scytonema Hofmanni* Ag Frémy, *op cit*, 1930, p 313, Fig 266, Geitler, *op cit*, 1925, p 268, Fig 317

Lat fil, 6·4–8 μ, when old upto 10 μ, crass vag, 1–1·5 μ, when old upto 2·2 μ, lat cell, 4·7–6·4 μ, long cell, 4·8–9 μ, lat het, 6·4 μ, long het, 9·6–12 μ

Habitat —On the cemented compound wall of a private garden

38 *Scytonema mirabile* (Dillw) Born Geitler, *op cit*, 1930–32, pp 776 and 777, Fig 498 *a–f*, Frémy, *op cit*, 1930, p 318, Fig 268, Bhâradwâja, "The Taxonomy of *Scytonema* and *Tolypothrix* including some new records and new species from India and Ceylon," *Revue Algalogique*, 1933, n 1–2, p 171, Fig 5, *A*

Lat fil, 13·2–16·5 μ, when old upto 19 μ, crass vag., 3·3–4 μ, when old upto 6·6 μ and thinned out at apices to 1·2 μ, lat trich, 6·6–9·5 μ, when old narrowed down to 4 μ, long cell, 3–6·6 μ, lat het, 6·6–8 μ, long het, 6·6–10 μ

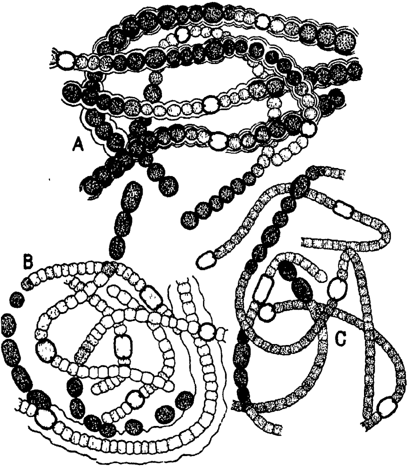
Habitat —On the moist bricks of a wall in the shade of a tree; on moist soil in a field

39 *Scytonema Bewsii* Fritsch and Rich "Contributions to our knowledge of the Freshwater Algæ of Africa 4 Freshwater and Sub-aerial algæ from Natal," *Trans Roy Soc S Africa*, Vol XI, 1924, p 364, Fig 23

Lat fil, 10–16 μ, when old upto 19 μ, crass vag, in old healthy filaments upto 4·9 μ, in old unhealthy ones upto 7 μ, lat trich, 4·8–7 μ, in old unhealthy ones narrowed down to 3·2 μ, at growing apices upto 10 μ, long cell, 11·2–23 μ, at apices 3·5–4·8 μ, lat. het, 6·6–10 μ, long het, 6·6–16·5 μ

Habitat —On the mud settled down on the rocks near the dam at Latif Shah, Benares State

The stratification of the sheath in this form is mostly diverging



Linckia (Roth.) Born. et Flah var *arvense* var nov , *B*—
Ag. var. *varians* var. nov , *C*—

5. *Nostocaceæ*

Genus *Cylindrospermum* Kuetzing

40 ***Cylindrospermum muscicola*** Kütz Frémy, *op cit*, 1930, p 377, Fig 313, Tilden, *op cit*, 1910, Pl. X, Fig 6, Ghose, *op cit*, 1926, Pl VII, Fig 15

Lat cell, 2·8–3 μ, long cell, 2 8–5 μ, lat het, 3·7–4 5 μ; long het, 4 5–6 (–7 5) μ, lat spor, 9–10 5 μ, long spor, 13 2–16 5 (–21 4) μ

Habitat :—On moist soil, singly or along with *Microcoleus chthonoplastes*, *Chroococcus pallidus* and others

Another form collected a few miles off Benares possesses heterocysts, which sometimes measure as much as 10 5 μ long

Genus *Nostoc* Vaucher

41 ***Nostoc paludosum*** Kütz Frémy, *op cit*, 1930, p 333, Fig 275, Tilden, *op cit*, 1910, Pl 6, Fig 38

Forma

Lat cell, 3–4 μ, long cell, 3 8–4 8 μ, lat het, 5 6–6 4 μ, long het, 6 6–8 μ, lat spor, 4 6–6 4 μ, long spor, 6 4–10 μ

Habitat —In the stagnant water of a crop-field along with *Nostoc piscinale* forma and others

The form differs from the type in having bigger spores

42 *Nostoc Linckia* (Roth) Born et Flah Frémy, *op cit*, 1930, p 333, Fig 276, Tilden, *op cit*, 1910, Pl VII, Fig 1, West, *Algæ*, 1916, Vol I, p 43, Fig 31, *A–C*

Var *arvense* var nov (Fig 4, *A*)

Plant-mass gelatinous, expanded, presenting an uneven surface, yellowish-brown to blue-green, filaments numerous, flexuous, trichomes frequently enveloped by a lamellated and yellowish-brown mucilaginous sheath that follows their contour, cells spherical or barrel-shaped, heterocysts almost spherical, usually not enveloped by any mucilage, spores in long chains, more or less spherical with a brown outer wall

Lat cell, 4–5 6 μ, long cell, 4 8–6 4 μ, lat het, 4 8–7 2 μ, long het, 4 8–6·4 μ, lat spor, 6·4–7 2 μ, long spor, 7–8 μ

Habitat —On water-logged soil in a crop-field

The variety is comparable to the type on account of its possessing (1) flexuous trichomes, (2) spherical or barrel-shaped cells, (3) almost spherical heterocysts and spores with a brown outer wall; but it differs from the same in the broader trichomes and heterocysts, and in commonly possessing a lamellated and brown mucilaginous sheath following the contour of the trichomes

43 *Nostoc piscinale* Kütz Frémy, *op cit*, 1930, p 334, Fig 277

Forma

Lat cell, 4–6 μ, lat het, 6 4–7 2 μ, lat spor, 6–10 μ

Habitat —In the stagnant water of a crop-field along with *Nostoc paludosum* and others

The form differs from the type in the slightly bigger dimensions of all parts

44. *Nostoc spongiæforme* Ag Frémy, *op cit* 1930, p 338, Fig 279 *a* and *b*, Tilden, *op cit*, 1910, Pl VII, Figs 4 and 5

Var *varians* var nov (Fig 4, *B*)

Plant-mass thin, spreading, blue-green, trichomes loosely entangled, sometimes individually enveloped by yellowish-brown mucilage, cells barrel-shaped, end-cell conical with a rounded apex, heterocysts barrel-shaped or cylindrical with rounded or flat ends, broader than the trichomes, spores in long chains, cylindrical with rounded ends, sometimes ellipsoidal, rarely spherical, with a smooth hyaline outer wall

Lat cell, 3–3 5 μ, long cell, 2–3 5 μ, lat het, 4 8–6 4 μ, long het, 5 6–8 μ, lat spor, 4–4 8 μ, long spor 4 8–10 μ

Habitat —On moist soil at the edge of a rain-water pool

The variety resembles the type in the loosely entangled filaments, the barrel-shaped cells, the barrel-shaped or cylindrical heterocysts, and the chains of ellipsoidal spores, but it differs in having a thin, blue-green and spreading stratum without any firm mucilaginous envelope, narrower cells that are never cylindrical and smaller heterocysts and spores, the latter being cylindrical or sometimes spherical with a hyaline outer wall

45 *Nostoc ellipsosporum* Rabenh Frémy, *op cit*, 1930, p 339, Fig 280, Tilden, *op cit* 1910, Pl VII, Figs 9 and 10

Var *violacea* var nov (Fig 4, *C*)

Plant-mass gelatinous, irregularly expanded, dark-violet, filaments flexuous, loosely entangled, light-violet, cells almost quadratic or cylindrical, with constrictions at the joints, heterocysts almost spherical or barrel-shaped or cylindrical, with rounded or flat ends, spores ellipsoidal almost spherical or cylindrical, with a hyaline smooth outer wall

Lat cell, 3·2–3 5 μ, long cell, 2 4–8 μ, lat het, 4–6 4 μ, long het, 4·8–8 μ, lat spor, 4·8–6 4 μ; long spor, 5 6–15 μ.

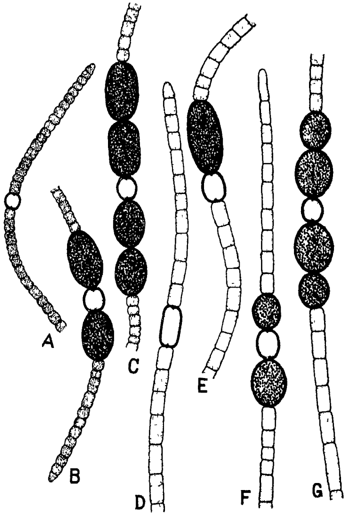


FIG. 5. *Anabæna Iyengari* Bhâradwâja var *tenuis* var. nov.; *unispora* Gardner var *crassa* var. nov.; *F–G—Anabæna aphanizomenoides* Forti var. *elipsospora* var. nov. All × 875.

Habitat :—On the sides of the steps of a village tank, above water-level.

The variety agrees with the type in the flexuous and laxly entangled filaments, in the cylindrical cells, in the spherical or cylindrical heterocysts, and in the long ellipsoidal or cylindrical spores with a hyaline smooth outer wall; but it differs in having a dark-violet stratum, narrower trichomes of light violet colour, comparatively shorter cells, smaller heterocysts, that are also barrel-shaped, and in the smaller dimensions of the spores possessing a hyaline outer wall

Genus *Anabæna* Bory

46 ***Anabæna ambigua*** Rao Rao, "A new species of *Anabæna* (*Anabæna ambigua* sp nov)," *Proc Ind Acad Sci*, 1937, Vol V, No 3, Sec B, pp 102 and 103, Figs 1 and 2

Long vag, 300-500 (-1,000) μ, crass vag, 10-50 μ, long trich, 250-300 μ; lat cell, 4·9-6·6 μ, long cell, 3 3-5 μ, lat het, 6 4-9 (-10) μ, lat. spor, 8 4-10 9 μ, long spor, 13 3-16 2 μ

Habitat :—Free-floating or attached to grass-blades and roots of *Lemna* and *Trapa* in some ponds near the Benares Hindu University

47 ***Anabæna Iyengari*** Bhâradwâja Bhâradwâja, "The Myxophyceæ of the United Provinces, India—I," *Proc Ind Acad Sci*, Vol 2, No 1, Sec B, 1935, Fig 6, *H-K*

Var *tenuis* var nov (Fig 5, *A-C*)

Plant-mass floccose, thin, free-floating, pale blue-green Trichomes single, straight or irregularly curved, end-cells conical with rounded apices Cells barrel-shaped, as long as broad or slightly shorter or longer than broad Heterocysts more or less barrel-shaped, sometimes sub-spherical Spores ellipsoidal or cylindrical with rounded ends, single or in pairs on either side of a heterocyst, with a smooth hyaline outer wall

Lat cell, 3 5-4 5 μ, long cell, 3-6 4 μ, rarely 7 5 μ, lat het, 4·8-6·4 μ, long het, 5 2-9 μ, lat spor, 7 5-9 6 μ, rarely 10·5 μ, long spor, 9-19·5 μ, rarely 21 μ

Habitat :—In a pond on the University grounds, along with *Dactylococcopsis raphidioides* forma, *Calothrix marchica* var *intermedia*, *Anabæna fertilissima* sp nov, *Oscillatoria animalis*, *Lyngbya Digueti* and sterile filaments of *Oedogonium* and *Spirogyra*

The variety resembles the type in the barrel-shaped cells, conical end-cells with rounded apices, barrel-shaped heterocysts and ellipsoidal spores, that are on either side of a heterocyst, but differs from the same in having narrower trichomes, smaller heterocysts and comparatively smaller spores (that are also cylindrical) with a hyaline outer wall and situated singly or in pairs on either side of a heterocyst

48 *Anabæna unispora* Gardner Geitler, *op cit*, 1930–32, p 901, Fig 580 *b*

Var *crassa* var nov (Fig 5, *D* and *E*)

Plant-mass soft, mucilaginous Trichomes free, long, more or less straight, tapering at extreme ends, constricted at joints, end-cells with rounded apices Cells cylindrical, sometimes almost quadratic Heterocysts single, cylindrical or ellipsoidal, sometimes pressed from both ends Spores single, adjoining heterocysts, long ellipsoidal, sometimes pressed from both ends, with a smooth hyaline outer wall

Lat cell, 4 8–6 6 μ, long trich, 500–700 μ, long cell, 4 5–13 2 μ, lat het, 5–8 2 μ, long het, 7·4–16 5 μ, lat spor, 9 6–15 μ, long spor, 23–31 5 μ

Habitat —In a rain-water pool, along with sterile filements of *Spirogyra* and *Oedogonium*, floating on the stagnant water of a rice-field

The variety agrees with the type in possessing cylindrical cells, constrictions at septa, end-cells with rounded apices and single ellipsoidal spores on only one side of a heterocyst*, but it differs from the same in having broader trichomes and narrower spores with a hyaline outer wall

49 *Anabæna aphanizomenoides* Forti Geitler, *op cit*, 1930–32, p 876, Fig 556

Var *ellipsospora* var nov (Fig 5, *F* and *G*)

Thallus free-floating, thin, floccose, pale blue-green Trichomes single, straight or bent, tapering at the ends, with constrictions at the joints, end-cells conical with rounded apices Cells quadratic or upto three times as long as broad Heterocysts single, intercalary, ellipsoidal, rarely spherical Spores ellipsoidal sometimes pressed from both ends, one or two on each side of a heterocyst, with a hyaline outer wall

Lat trich, 3 3–4 μ, at top 1 6 μ, long cell, 3 3–11 μ, lat het, 6–6 6 μ, long het, 6–11 6 μ, lat spor, 9 6–13 5 μ, long spor, 11 6–19 8 (–23) μ

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* Since the author of *Anabæna unispora* has not given any idea of the shape and the actual dimensions of the heterocysts, it is not possible to compare them with those of the present form. But the original figure of the type shows that the heterocysts are cylindrical as found in the form under discussion The Benares alga, however, possesses ellipsoidal heterocysts as well

Habitat —In a rain-water pool, along with *Aulosira Fritschii*, *Cosmarium* sp, *Closterium* sp, and several others

The variety agrees with the type in possessing quadratic and cylindrical cells, ellipsoidal heterocysts and one or two spores on each side of a heterocyst, the former with a hyaline outer wall, but it differs in the slightly narrower trichomes, in the absence of gas-vacuoles in the cells, in the longer heterocysts and in the bigger ellipsoidal spores

50 *Anabæna sphærica* Born et Flah var *attenuata* Bhâradwâja Bhâradwâja, *op cit*, 1935, p 104, Fig 5, *G* and *H*

Lat trich, 3·3–5 μ, long cell, 3 3–4 μ, lat het, 4 8-6 4 (-7 5) μ, lat spor, 10–12 μ, long spor, 9 8–14 6 μ

Habitat —On soil submerged in water at the edge of a pool

This variety, as originally reported, possessed only single spores on either side of a heterocyst, but in the present form, spores are also met with in pairs on each side of a heterocyst

51 *Anabæna fertilissima* sp nov (Fig 6, *A–C*)

Trichomes single, straight or bent, with almost rounded end-cells, cells barrel-shaped, heterocysts almost spherical, spores in long chains, often making the whole trichome sporogenous, adjoining the heterocysts but developed centrifugally, almost spherical, with a smooth hyaline outer wall

Long trich, upto 350 μ, lat trich, 5–5 6 μ, at apex 4 μ, long cell, 4·8–8 μ, lat het, 6 4–8 4 μ, lat spor, 4 8-8 μ, long spor, 3 2–8 8 μ

Habitat.—In a pond on the University grounds, along with *Dactylococcopsis raphidioides* forma, *Calothrix marchica* var *intermedia*, *Anabæna Iyengarii* var *tenuis*, *Oscillatoria animalis*, *Lyngbya Digeutii* and sterile filaments of *Spirogyra* and *Oedogonium*

The important feature in this alga is the formation of spores in long chains, so much so that practically the whole of the trichome becomes sporogenous. It comes close to *Anabæna sphærica* Born et Flah on account of the barrel-shaped cells, rounded end-cells and spherical heterocysts and spores, but it differs in the spores being smaller and formed in long chains In the presence of spherical heterocysts and spores in chains, the present alga agrees with *Anabæna gelatinicola* Ghose, but it differs from the Lahore form in the presence of narrower trichomes that are never coiled, rounded end-cells and much longer chains of smaller spores adjoining the heterocysts The barrel-shaped cells and the chains of spores characteristic of this alga also recall ***Anabæna variabilis*** Kütz., ***A. æruginosa*** Gardner, *A. Iyengari* Bhâradwâja, and ***A. doliolum*** Bhâradwâja, but it differs from all these four species in the spores being spherical. It further differs from the former two species in the presence of spores adjoining the heterocysts and from the latter two species in possessing spherical heterocysts

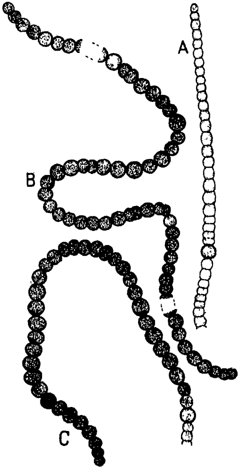

Fig. 6. *A*—vegetative and *B & C*—sporogenous portions of filaments of *fertilissima* sp. nov. All × 875.

6. *Oscillatoriaceæ*

Genus *Spirulina* Turpin

52. *Spirulina platensis* (Nordst.) Gom. Geitler, *op. cit.*, 1930–32, p. 922, Fig. 590 *d*, Frémy, *op. cit.*, 1930, p. 232, Fig. 205

Var. *tenuis* var. nov. (Fig. 7, *A* and *B*)

Plant-mass greyish-brown; trichomes pale blue-green, of uniform width, in regular spirals, without constrictions at the joints; end-cells with rounded apices; cells disc-shaped.

Lat. trich., 5·1–6·4 μ; long. cell., 1·6–2·5 (–3·3) μ; lat. spir., 30–43 μ; spat. inter duo spir., 40–52 μ.

Habitat:—In a waste-water drain, in a pond, along with *Oscillatoria chalybea*, Rajghat.

The variety agrees with the type in the uniform width of the trichomes, in the rounded apices of the end-cells, in the spirals being regular, and in the distance between the spirals; but it differs on account of the narrower trichomes, the broader spirals, the comparatively shorter cells, and the absence of constrictions at the septa.

53. *Spirulina major* Kütz. Geitler, *op. cit.*, 1930–32, p. 930, Fig. 595; Frémy, *op. cit.*, 1930, p. 235, Fig. 208; Tilden, *op. cit.*, 1910, Pl. IV, Fig. 46; Frémy, *op. cit.*, 1934, Pl. 31, Fig. 18; Carter, "A comparative study of the algal flora of two salt marshes, Part II," *Journal of Ecology*, Vol. XXI, I, 1933, p. 159, Fig. 2; Ghose, *op. cit.*, 1926, Pl. VI, Fig. 3.

Lat. trich., 1–1·4 μ; lat. spir., 3·2–3·5 μ; spat. inter duo spir., 2·4–3·2 μ.

Habitat:—On moist soil along with other algæ; planktonic in the tank of the Benares Electric Light and Power Supply Co., Ltd., along with *Chroococcus turgidus*, *C. minutus* and *Merismopedia tenuissima*.

Genus *Oscillatoria* Vauch.

54. *Oscillatoria sancta* (Kütz.) Gom. Frémy, *op. cit.*, 1930, p. 210, Fig. 177; Tilden, *op. cit.*, 1910, Pl. IV, Fig. 5; Carter, *op. cit.*, 1933, p. 159, Figs. 11 and 12; Geitler, *op. cit.*, 1925, p. 356, Fig. 418.

Lat. cell., 10–16 μ; long. cell., 2·5–4·8 μ.

Habitat:—On moist soil amidst flower pots in the Green House, University Botanical Garden, along with *Oscillatoria Ulrichii*; on moist soil along with *Oscillatoria formosa*.

Forma

Lat cell, 9·6–11·2 μ, long cell, 2–4 μ

The form has no constrictions at the joints

55 *Oscillatoria obscura* Brühl and Biswas "Algæ of the Bengal Filter-beds," *Journal of the Department of Science, Calcutta University*, 1922, Vol 4, Pl II, Fig 9

Lat cell, 4·1–4 8 μ, long cell, 1–1 3 μ

Habitat —On wet soil along with *Navicula* sp

56 *Oscillatoria anguina* (Bory) Gom Geitler, *op cit*, 1930–32, p 945, Fig 599 *b*

Lat trich, 6 6–8 2 μ, long cell, 1·5–2 5 μ

Habitat —In a waste-water drain; in a rain-water puddle, Chunar

57 *Oscillatoria chalybea* Mertens Geitler, *op cit*, 1930–32, p 956, Fig 608 *b*

Lat cell, 7–9 6 μ, at top 6 6 μ, long cell, 3–6 6 μ

Habitat —On wet soil, along with *Oscillatoria homogenea*, Mussoorie

58 *Oscillatoria tenuis* Ag Geitler, *op cit*, 1930–32, p 960, Fig 611 *g*, Tilden, *op cit*, 1910, Pl IV, Fig 17

Lat cell, 4 5–6 6 μ, long cell, 2 5–5 μ

Habitat —On moist soil, in a road-side water course, Shivpur, Benares, along with other algæ, in rain-water ditches on waste ground

59 *Oscillatoria pseudogeminata* G Schmidle Geitler, *op cit*, 1930–32, p 966, Fig 616

Lat cell, 1 6–1 8 μ, long cell, 1–2 μ

Habitat —On moist soil

Forma

Lat trich, 1 6–2 μ, long cell, 1·8–5 μ

Habitat —In stagnant water of a ditch near a well

The form possesses much longer cells as well

60 *Oscillatoria quadripunctulata* Brühl and Biswas Brühl and Biswas, *op cit*, 1922, p 5, Pl I, Fig 6, Biswas, "Road Slimes of Calcutta," *Jour Dept Sci, Cal Univ*, 1925, Vol VII, p 10, Pl II, Fig 11 *a–d*, Geitler, *op cit*, 1930–32, p 966

Lat trich,, 1 6–1 8 μ; long cell, 3–6 4 μ

Habitat —On moist soil along with other algæ; in a pond along with other algæ

61. *Oscillatoria homogenea* Frémy Frémy, *op cit*, 1930, p 221, Fig. 184

Lat. cell, 3·3–3·5 μ, long cell, 3·5–4·6 μ

Habitat —On wet soil, along with *Oscillatoria chalybea*, Mussoorie

62 *Oscillatoria Okeni* Ag Tilden, *op cit*, 1910, Pl IV, Fig 35, Geitler, *op cit*, 1925, p 372, Fig 463

Lat cell, 5·5–6·6 μ, long cell, 3–4·5 μ

Habitat —On moist soil along with *Oscillatoria sancta* and others, on water-logged soil

63 *Oscillatoria formosa* Bory Geitler, *op cit*, 1930–32, p 970, Fig 619 *b*

Lat trich, 4·5–6·6 μ, long cell, 1·8–4·5 μ

Habitat —On moist soil, along with *Oscillatoria pseudogeminata*, on moist rocks, along with *Phormidium subfuscum*, Mussoorie, on moist soil, along with *Oscillatoria sancta* and *O princeps*, on soil, along with other algæ, in a waste-water drain

64 *Oscillatoria claricentrosa* Gardner Geitler, *op cit*, 1930–32, p. 964, Fig 615 *c*

Forma *bigranulata* form nov (Fig 7, C)

Lat trich, 2–2·5 μ, long cell, 5–10 μ

Habitat —In stagnant water of a drain, along with sterile filaments of *Spirogyra* and *Oedogonium*

The form differs from the type in the presence of two granules on either side of a cross-wall and in the trichomes showing a more gradual tapering

65 *Oscillatoria rubescens* D C Geitler, *op cit*, 1930–32, p 973, Fig 620 *a* and *b*

Forma.

Lat. trich, 4·8–6·4 μ, long cell, 1·2–4 μ

Habitat — On wet soil, Chunar

But for the presence of narrower trichomes, the Benares form agrees with the type in all respects

66 *Oscillatoria Lemmermanni* Wolosz Geitler, *op cit*, 1930–32, p 969, Fig 618 *i*

Lat trich, 2·2–2·8 μ, long cell, 2·5–5 μ

Habitat —On moist soil along with *Phormidium Jadinianum* forma

67 *Oscillatoria animalis* Ag Geitler, *op cit*, 1930–32, p 950, Fig 603 *e*

Lat trich , 2·5–3·3 μ ; long cell., 2–5·2 μ.

Habitat :—On the moist sides of the cemented pavement of a well ; in a pond on the University grounds, along with *Dactylococcopsis raphidioides* forma, *Calothrix marchica* var *intermedia*, *Anabæna fertilissima* sp nov , *A Iyengari* var. *tenuis*, *Lyngbya Digeuti* forma and sterile filaments of *Spirogyra* and *Oedogonium* , in a ditch along with *Oscillatoria sancta* and others

68 *Oscillatoria acuminata* Gom Tilden, *op. cit* , 1910, Pl. IV, Fig 29.

Forma

Lat cell , 3–3·8 μ ; long cell., 1–3·8 μ

Habitat —On moist soil.

The form differs from the type in the smaller dimensions of the cells

69 *Oscillatoria salina* Brühl and Biswas Geitler, *op cit* , 1930–32, p 979, Fig 624

Lat. cell , 3·3–4·8 μ , long cell , 1·5–2 μ

Habitat —In earthen water-pans in a green house, along with *Cylindrospermum indica* and *Cocconeis* sp , on moist soil in a drain, Cantonment area , on moist soil, University area

Unlike the type, the Benares alga is a fresh-water form

Genus *Phormidium* Kütz

70 *Phormidium Bohneri* Schmidle " Beitrage zur Algenflora Afrikas," Engler's *Botanische Jahrbucher*, 1902, 30, Taf. II, Fig. 11

Forma

Lat fil., 3–3·7 μ; lat cell , 2·2–2·8 μ , long. cell , 1·6–2·8 μ

Habitat —On the cemented surface near the waste-water outlet of a house, Ramnagar

The form differs from the type in the presence of the broader and the closely entangled filaments with a persistent sheath

71 *Phormidium cebennense* Gom Frémy, *op cit* , p 147, Fig 129

Lat trich , 1·8–2 μ ; long cell , 1–2 μ.

Habitat.—On the plinth of the College building near the outlet of a drain, along with *Phormidium anomala* sp nov

72 *Phormidium mucosum* Gardner Geitler, *op cit* , 1930–32, p 1012, Fig 646 *b*

Var *arvense* var. nov (Fig 7, *D* and *E*).

Plant-mass thick, fragile, blue-green to greyish-blue Filaments loosely entangled. Sheath thick, firm, hyaline, unstratified. Trichomes of uniform width, not constricted at the joints; apical cells with rounded apices, without calyptra or cap. Cells quadratic or almost quadratic or slightly longer than broad.

Lat. fil., 3·2–5·2 μ; crass. vag., upto 2 μ, lat. trich., 1·8–2·5 μ, long. cell., 1·5–3·6 μ.

Habitat:—In stagnant rain-water of a crop-field.

The variety agrees with the type in all respects except that it has narrower filaments and trichomes, the latter possessing shorter cells.

73. *Phormidium Retzii* (Ag.) Gom. Geitler, *op. cit.*, 1930–32, p. 1012, Fig. 647 *a–d*.

Lat. fil., 4·5–7 μ, long. cell., 4·5–8 μ.

Habitat.—On the sides of the water storage tanks of the Benares Water Works, on moist stones near the dam, Latif Shah, Benares State.

74. *Phormidium ambiguum* Gom. Geitler, *op. cit.*, 1930–32, p. 1012, Fig. 647 *e*, Ghose, "The Myxophyceæ of Rangoon, II," *Journ. Burma Res. Soc.*, 1927, Vol. XVI, Part III, pp. 220–26, Pl. XI, Fig. 4.

Forma.

Lat. cell., 3·4 μ, long. cell., 1·5–2·8 μ.

Habitat:—On the sides of the cemented water reservoir, University Botanical Garden.

The form has slightly narrower trichomes than those of the type.

75. *Phormidium subincrustatum* Fritsch and Rich. Fritsch and Rich, "Contributions to our knowledge of the Fresh-water Algæ of Africa, 7, Fresh-water algæ (exclusive of Diatoms) from Griqualand West," *Trans. Roy. Soc. S. Africa*, 1929, Vol. VXIII, Parts 1 and 2, p. 84, Fig. 27 *I–L*.

Lat. trich., 4·7–5·8 μ, crass. vag., upto 0·5 μ; long. cell., 2·5–8 μ.

Habitat.—On moist soil, along with *Microcoleus chthonoplastes* and others.

76. *Phormidium subfuscum* Kütz. Geitler, *op. cit.*, 1930–32, p. 1023, Fig. 652 *d–g*.

Lat. cell., 8·4–11·7 μ, long. cell., 1·8–3 μ.

Habitat.—On moist soil, along with *Oscillatoria formosa*.

The calyptra in this form is rounded instead of being pointed.

77. *Phormidium favosum* (Bory) Gom. Geitler, *op. cit.*, 1930–32, p. 1023, Fig. 652 *a* and *b*.

Forma.

Lat. cell., 4–6 μ; long. cell., 2·4–3·5 μ.

Habitat:—On the sides of a big water reservoir.

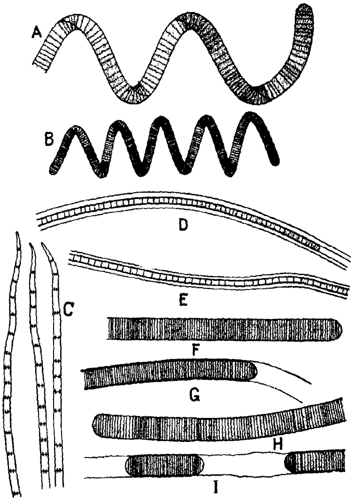

Fig 7 *A*—Terminal portion of the trichome and *B*—entire plant of *Spirulina platensis* (Nordst) Gom var *tenuis* var nov , *C*—Terminal portions of *Oscillatoria claricentrosa* Gardner forma *bigranulata* form nov , *D & E*—portions of filaments of *Phormidium mucosum* Gardner var *arvense* var nov.; *F.-I*—portions of filaments of *Phormidium anomala* sp. nov. *B* × 425 , all the rest × 875

The form exactly resembles the type except for the presence of shorter cells

78 *Phormidium autumnale* (Ag.) Gom Geitler, *op cit*, 1930–32, p 1023, Fig 652 *k* and *l*, Frémy, *op cit*, 1934, Pl 24, Fig 4, Carter, *op cit*, 1933, p 156, Fig 7

Lat cell, 4–4·8 μ, long cell, 2·4–4·8 μ

Habitat —On the stony steps of a tank near water-level

79 *Phormidium anomala* sp nov (Fig 7, *F–I*)

Thallus thick, expanded, soft, mucilaginous, deep blue-green to green Trichomes sub-parallel, of uniform width, without constrictions at the joints Sheath thin, colourless, unstained with chlor-zinc-iodide, peristent or dissolved Cells disc-shaped, much broader than long, end-cells bluntly rounded, without cap or calyptra

Crass strat, 3–6 mm, lat trich, 8–10 μ, long cell, 0·8–1·2 (–2) μ

Habitat —On the plinth of the College building, near the outlet of a drain, along with *Phormidium cebennense*

This alga approaches *Phormidium ambiguum* Gom and *Phormidium subincrustatum* Fritsch and Rich in the presence of an expanded stratum, the uniform width of the trichomes, the absence of constrictions at the joints, and the rounded apices for the end-cells, which are without a cap or calyptra, but it differs from both these species in having shorter and wider cells * It further differs from the former species in the filaments being more or less parallel, the sheath being always thin and unstratified, and remaining unstained with chlor-zinc-iodide, the absence of granules near the septa and of the gas-vacuoles in the cells The Benares alga, while further agreeing with *Phormidium subincrustatum* in the sub-parallel trichomes and the thin, diffluent and unstratified sheath, differs from it in the thallus being thicker and without any impregnation of lime

Genus *Lyngbya* Agardh

80 *Lyngbya gracilis* Rabenh Geitler, *op cit*, 1930–32, p 1040, Fig. 657 *a*; Frémy, *op cit*, 1934, Pl 26, Fig 3

Lat fil, 8–11·8 μ, crass vag, 0·8–1·8 μ, lat trich, 5·6–8·3 μ, long cell, 2–6·4 μ.

Habitat —In the water storage tank of the Benares Water Works, along with *Chamaesiphon sideriphilus* var *glabra*

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* Fritsch and Rich have not mentioned the length of the cells in *Phormidium subincrustatum*, but their figures show them to be shorter than broad or almost quadratic.

81. *Lyngbya spiralis* Geitler Geitler, *op. cit*, 1930–32, p 1042, Fig 659

Lat. fil, 5–5·8 μ, crass vag, 0·3 μ, lat trich, 4·8–5 μ, long. cell., 1·5–2·5 μ

Habitat —Planktonic in a rain-water pool, along with *Aphanothece bullosa*.

82. *Lyngbya limnetica* Lemm Lemmermann, *op cit*, 1910, p 102, Fig 8

Lat fil, 1·5–2 μ, lat cell, 1·2–1·6 μ, long cell, 1–2·5 μ

Habitat —In an ornamental water reservoir of a private garden, along with *Microcystis æruginosa* var. *elongata*, *Oscillatoria Annæ* and *Oedogonium* sp.

83 *Lyngbya dendrobia* Brühl and Biswas "Commentationes Algologicæ ii algæ epiphyticæ epiphloiæ indicæ or Indian Bark Algæ," *Jour Dept. Sci*, *Cal Univ*, 1923, 5, Pl III, Fig 11 *a–c*, Geitler, *op cit*, 1930–32, p 1051

Forma

Lat fil, 9·6–13·2 μ, crass vag, 0·8–3 μ, lat trich, 6·6–8·8 μ, long cell, 4–8 μ

Habitat —On moist soil, spreading among *Riccia* sp and grass blade

The form differs from the type in possessing narrower trichomes and thicker sheath

84 *Lyngbya corticola* Brühl and Biswas Brühl and Biswas, *op cit*, 1923, Pl IV, Figs 13 *a–d*, Geitler, *op cit*, 1930–32, p 1052.

Forma

Lat fil, 18·4–25·6 μ, crass vag, 2·4–8 μ, lat cell, 10·4–12·8 μ, long cell, 4–8 μ

Habitat —On moist soil, University area

The form differs from the type in the sheath being very thick and stratified.

85. *Lyngbya æstuarii* Liebm var *arbustiva* Brühl and Biswas Brühl and Biswas, *op cit*, 1923, Pl II, Fig 9 *a–c*; Geitler, *op cit*, 1930–32, p 1053

Lat fil, 22·8–26·4 μ, crass. vag, 2·5–4 μ; lat. trich, 16–18 μ, long. cell, 4·5–8 μ

Habitat :—On the bark of *Eujenia Jambolana* by the side of the road leading to Allahabad

86. *Lyngbya arboricola* Brühl and Biswas. Brühl and Biswas, *op. cit.*, 1923, Pl. III, Fig. 10 *a–e*, Geitler, *op cit*, 1932, p. 1053

Lat fil, 19 2–23 μ, crass vag, 2–4 μ, lat trich, 16–17 μ, long cell, 4–6·4 (–9) μ

Habitat —On the bark of *Mangifera indica* along with *Lyngbya trunicola*

87 *Lyngbya trunicola* Ghose Ghose, *op cit*, 1923, Pl 31, Fig 6

Lat fil, 15–16 5 μ, crass vag, 0 8 μ, lat trich, 12–15 μ, long cell, 1·5–4 5 μ

Habitat —On the bark of *Bassia latifolia* and *Mangifera indicæ*, either singly or along with *Lyngbya arboricola*, University Botanical Garden

88 *Lyngbya rubida* Frémy Frémy, *op cit*, 1930, p 185, Fig 155

Forma

Lat fil, 6–8 μ, lat trich, 4 8–5 μ, long cell, 4–8 μ

Habitat —In a stagnant pond

The form differs from the type in having slightly broader trichomes, shorter cells and a hyaline sheath

89 *Lyngbya ceylanica* Wille Geitler, *op cit*, 1930–32, p 1055, Fig 668 *a*, Ghose, "On a collection of Myxophyceæ from Mergui and some neighbouring islands," *Journal of the Burma Research Society*, 1927, Vol XVII, Part III, pp 244–51, Pl III, Fig 11

Lat fil, 12·8–19 μ, crass vag, 3 2–4 μ, lat trich, 9 6–11 2 μ, long cell, 4 8–6 4 μ

Habitat —On moist soil along with *Microcoleus chthonoplastes*

The sheath in the Benares form is thicker than that of the type

90 *Lyngbya lutea* (Ag) Gom Geitler, *op cit*, p 1058, Fig 670 *a* and *b*, Frémy, *op cit*, 1934, Pl 28, Fig 4 *a–c*, Carter, *op cit*, 1933, p 164, Figs 5 and 6

Lat fil, 4 8–5 μ, lat trich, 3 8–4 μ, long cell, 2·4–3 8 μ

Habitat —In a cemented drain, University Botanical Garden

The sheath in this form is thin and unstratified

91 *Lyngbya Digeuti* Gom. Geitler, *op cit*, 1930–32, p 1038, Fig 656 *e*

Forma

Lat fil, 1·5–2 3 μ, lat trich, 1 4–2·2 μ, long cell, 1 5–3 2 μ

Habitat —In a pond on the University grounds, along with *Dactylococcopsis raphidioides* forma, *Calothrix marchica* var. *intermedia*, *Anabæna Iyengari* var *tenuis*, *A fertilissima* sp nov, *Oscillatoria animalis* and sterile filaments of *Spirogyra* and *Oedogonium*

The form is characterised by the possession of narrower filaments.

92 *Lyngbya confervoides* Ag. Tilden, *op cit*, 1910, Pl. V, Fig 39, Frémy, *op cit*, 1934, Pl. 28, Fig 2; Carter, *op cit*, 1933, p 162, Fig. 11, 1 and 2

Lat fil., 19 8–23·2 μ, crass vag, upto 5 μ; lat trich, 13 2–19·2 μ; long cell, 2–4 μ

Habitat :—In an ornamental reservoir of a private garden under the shade of the closely spreading leaves of *Nelumbium* sp.

93 *Lynbgya ærugineo-cærulea* (Kütz) Gom. Frémy, *op cit*, 1930, p 193, Fig 157, Ghose, *op cit*, 1926, Pl VI, Fig 7

Lat fil, 6·4–8 μ, lat trich, 5·1–6 4 μ, long cell, 1·8–4 8 (–5·6) μ

Habitat —In a stagnant pond, Chunar

94 *Lyngbya putealis* Mont Geitler, *op cit*, 1930–32, p 1063, Fig 675 *b*, Frémy, *op cit*, 1930, p 193, Fig 159 *a* and *b*

Lat fil, 8–11 2 μ, crass vag, upto 0·8 μ, lat trich, 6 4–9 6, average 8 μ, long cell, 3–10 5 μ

Habitat —In the stagnant water of an irrigation channel, Ramnagar

95 *Lyngbya Martensiana* Menegh Geitler, *op cit*, 1930–32, p 1064, Fig 676

Forma

Lat fil, 8–8 8 μ, crass vag., 0 8 μ, lat trich, 5 6–6 4 μ, long cell, 2–4 8 μ

Habitat —On water plant at the edge of a rain-water pool

The form differs from the type in the sheath being always smooth and the cells being sometimes longer

96 *Lyngbya stagnina* Kütz Geitler, *op cit*, 1930–32, p 1066, Fig 679 *b*.

Forma

Lat fil, 10–12 μ, lat. trich, 8 5–9·5 μ, long cell, 5–10 μ

Habitat :—In a stagnant puddle by the side of the River Ganges along with *Cladophora* sp and *Gomphonema* sp

The form differs from the type in having narrower trichomes and longer cells* without granules near the septa

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*** From the description of the type it is clear that the cells are much shorter than broad, but Skuja's figure shows the cells to be almost quadratic or only slightly shorter than broad, just like those of the form under discussion.**

97 *Lyngbya major* Menegh Tilden, *op cit*, 1910, Pl 5, Fig 46, Geitler, *op cit*, 1930–32, p 1066, Fig 679 *a*, West, *op cit*, 1916, p 42, Fig. 28 *A*

Lat. fil., 19·2–20·8 μ, crass vag, 3·2–4 μ, lat trich, 12·8–14·4 μ, long cell, 2–4 μ

Habitat :—On moist soil in shade

Genus *Symploca* Kützing

98. *Symploca muralis* Kütz Geitler, *op cit*, 1930–32, p 1125, Fig. 732; Frémy, *op. cit*, 1930, p 129, Fig 113 *a* and *b*, West, *op cit.*, 1916, p 23, Fig 15 *E*.

Forma

Lat fil., 5·2–7·5 μ, crass vag, upto 2·5 μ, lat trich, (3 2–) 4–5 μ, long cell, 2 4–5 6 μ.

Habitat :—On moist soil, University area

The form differs from the type in having broader trichomes and sometimes longer cells

Genus *Microcoleus* Desmazieres

99 *Microcoleus chthonoplastes* Thuret Geitler, *op cit*, 1930–32, p 1134, Fig 739; Carter, *op cit*, 1933, p 166, Figs 15–17.

Diam fil, 30–100 μ, lat vag, 15–65 μ, lat cell, 4–5 μ, long cell. 4–8 μ

Habitat —On moist soil along with other algæ

100 *Microcoleus sociatus* W et G S West Frémy, *op cit*, 1930, p. 83, Fig 85 *a* and *b*.

Diam fil, 30–45 μ, lat vag, 2–10 μ, lat trich, 2·4–2·8 μ, long cell, 4 8–6 μ

Habitat —On moist soil along with other algæ

The writer takes this opportunity to express his great indebtedness to Professor Y Bhâradwâja, for his kind guidance and criticism throughout the course of this investigation

THE PROTEINS OF GROUNDNUT (PEANUT), *ARACHIS HYPOGAEA*, LINN.

By W. V. Kotasthane and N. Narayana
(From the College of Agriculture, Poona.)

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India produces a large variety of oilseeds in abundance. Among them, groundnut is of supreme importance as it occupies a third of the total area under cultivation of oilseeds. The total production is more than three million tons which represents nearly half the world's output of this seed.

The seed is eaten as such or after being fried. But the main use of groundnut is for its oil which is nearly 50 per cent of the seed. The cake which is available in large quantities is mainly used as cattle food or as manure. Many workers have pointed out the high nutritive value of groundnut cake for human consumption (Daniel, 1917; Wallis, 1917). Johns and Jones (1916–18) and Daniel and Menaul (1921) have isolated the proteins of the groundnut cake and analysed them. In India there has been practically no work on the nature of the proteins of oilseeds. The only solitary reference to oilseed proteins is that of Narayana and Srinivasaya (1936) on the proteins of sandal seed, which though edible is not used as a food-stuff. In this investigation, therefore, an attempt is made to get an idea of the nutritive value of groundnut cake by making a complete and detailed analysis of its proteins.

Material.—The seeds of the two common varieties of groundnut, Local and Spanish, were employed. The oil was expressed in a local *ghani* and the cakes obtained were utilized for the isolation of proteins. Below are given the analyses of the two cakes used in this investigation.

Table I

	Local	Spanish
Moisture	4·31	5·66
*Ash	4·18	4·83
Ether Extract	20·84	10·05
†Crude Protein (N × 6·25)	52·50	62·22
Crude Fibre	2·42	3·42
Carbohydrates	15·75	13·82
	100·00	100·00

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* Sand . . 0·40 0·81
† Nitrogen . . 8·40 9·95.

Experimental.

As the preliminary experiments showed that the presence of even a small quantity of oil in the cake exerts a strong inhibiting action on the peptisation of the proteins, the cake was extracted with ether to make it completely free of oil. 75 per cent of the total nitrogen was extractable with 10 per cent. sodium chloride solution at room temperature and most of it could be precipitated as a globulin

Isolation of the Proteins —

Total Globulins —The cake was extracted with 10 per cent saline solution. Total globulins were isolated from this extract by (i) dilution and acidification with acetic acid, (ii) by dialysis and (iii) by saturation with ammonium sulphate Three preparations were thus obtained

Arachin and Conarachin —Johns and Jones (1916-18) have shown that two globulins—Arachin and Conarachin—can be obtained from the saline extract by fractional precipitation with ammonium sulphate. The saline extract of the cake was saturated with ammonium sulphate to 0·25 saturation The precipitate of Arachin obtained was redissolved in 10 per cent saline solution and was reprecipitated from this either by dilution and acidification or by dialysis Thus two preparations of this protein were obtained

Conarachin was obtained by dialysing the filtrate from *Arachin* against cold distilled water to make it free from ammonium sulphate Another preparation of the same protein was prepared by fully saturating the filtrate with ammonium sulphate This was redissolved in 10 per cent saline solution and dialysed

All the above preparations were washed with distilled water several times and dehydrated by washing with graded strengths of alcohol and finally by ether The preparations were dried in vacuum and powdered to pass through a 100-mesh sieve. All the preparations were light powders, greyish white in colour. Arachin constituted the major part of the total globulins of groundnut, its yield being ten times that of Conarachin

The table below gives the average of duplicate elementary analyses of the various preparations of the three proteins from each of the two varieties.

TABLE II. *Total Globulins*

	Local			Spanish		
Preparation No.	I	II	III	I	II	III
Method	Dialysis	Dilution	Salt Saturation	Dialysis	Dilution	Salt Saturation
Moisture	7·60	8·20	7·18	6·80	7·56	5·41
Ash	0·63	0·70	0·67	0·61	0·69	0·64
*Nitrogen	17·77	17·74	17·65	17·67	17·62	17·63
*Sulphur	0·42	0·38	0·43	0·40	0·43	0·39

Arachin

	Local		Spanish	
Preparation No	I	II	I	II
Method	Dilution	Dialysis	Dilution	Dialysis
Moisture	5·98	7·50	6·08	6·42
Ash	0·18	0·16	0·22	0·18
*Nitrogen	17·96	17·88	17·89	17·83
*Sulphur	0·38	0·40	0·40	0·36

Conarachin

	Local		Spanish	
Preparation No.	I	II	I	II
Method	Dialysis	Salt-Saturation	Dialysis	Salt-Saturation
Moisture	7·92	9·08	10·02	8·82
Ash	1·99	1·48	1·96	1·64
*Nitrogen	16·95	16·97	16·89	16·95
*Sulphur	0·95	0·99	1·01	0·97

* On ash and moisture free basis.

Analysis of Proteins.—

All the proteins were analysed by Van Slyke's Nitrogen Distribution Method (1911) as modified by Plimmer and Rosedale (1925), Knaggs (1923), Daft (1929) and Thimman (1926) Every step such as acid hydrolysis, precipitation by phosphotungstic acid, etc, has an important bearing on the final results It was found that 48 hours digestion with 20 per cent hydrochloric acid was sufficient to complete the hydrolysis, *i e*, to yield the maximum amount of amino nitrogen After removal of acid as completely as possible, the amount of solid calcium oxide added to neutralize the slight acidity of hydrolysate and to set free all the amide nitrogen was throughout kept at 3·5 gm per 1000 mg nitrogen Again, the volume in which the precipitation of the bases by phosphotungstic acid was allowed to take place was 200 c c containing 350–360 mg of nitrogen and enough hydrochloric acid to make it exactly normal Thus the concentrations of calcium chloride, nitrogen and acidity were controlled The solution was first heated to boiling, to which was added a boiling solution of phosphotungstic acid When this was done in cold, as described by Van Slyke, the precipitate could not be redissolved by heating on the water-bath

The following tables give the average of duplicate analyses of the various preparations of the three proteins from each of the varieties

It will be seen that the analyses of the various preparations of the three proteins from each of the two varieties of cakes agree with one another This shows that all the preparations of each protein are equally pure Therefore, the preparations were mixed and used for the separate estimation of arginine, cystine, tyrosine and tryptophane, as described below

Arginine—This was estimated directly in the acid hydrolysate of protein after removing ammonia by lime according to the method of Plimmer and Rosedale (1925) who have shown that the arginine value as obtained from the basic fraction of Van Slyke's analysis is lower than the true value as obtained by direct estimation in the hydrolysate

Cystine.—Plimmer and Lowndes (1927) have shown that only 40 per cent of the cystine is precipitated by phosphotungstic acid along with the other bases Hence this was estimated by the Folin and Marenzi (1929) method as modified by Remington (1930)

Tyrosine and Tryptophane—These were estimated according to Folin and Marenzi's micro method (1929) in which tyrosine is separated from tryptophane by the precipitation of the latter by mercuric sulphate

Table IV gives the percentage of these amino-acids in the two varieties

TABLE III

Nitrogen Distribution in Proteins (in Percentage of Total Nitrogen)
Total Globulins

	Local			Spanish		
Preparation No.	I	II	III	I	II	III
Method .	Dialysis	Dilution	Salt Saturation	Dialysis	Dilution	Salt Saturation
Melanin, insol	0·50	0·48	0·58	0·71	0·67	0·60
Melanin, adsorbed by lime . ..	0·92	0·87	1·00	0·49	0·53	0·58
Amide	11·47	11·62	10·87	11·87	11·26	12·03
Basic:—						
Arginine . .	22·83	21·98	23·08	21·64	22·17	23·03
Histidine ..	2·23	2·89	2·56	2·47	2·21	2·58
Lysine . .	4·96	5·03	4·59	5·10	4·80	5·40
Cystine .. .	0·56	0·59	0·44	0·54	0·60	0·57
Non-Basic:—						
Amino . .	54·49	54·82	55·48	53·77	54·16	53·94
Non-Amino ..	1·92	2·06	1·63	1·93	1·96	2·03
TOTAL ..	99·88	100·34	100·23	98·52	98·38	99·76

	Local		Spanish	
Preparation No. ..	I	II	I	II
Method ..	Dialysis	Dilution	Dialysis	Dilution
Melanin, insol. ..	0·39	0·29	0·56	0·34
Melanin, adsorbed by lime	0·47	0·73	0·29	0·53
Amide	11·53	11·03	12·82	10·92
***Basic*.—**				
Arginine	22·56	22·60	22·37	21·87
Histidine ..	3·13	2·85	3·03	2·89
Lysine	4·91	4·38	4·49	4·97
Cystine	0·47	0·57	0·47	0·55
***Non-Basic*.—**				
Amino	55·98	56·06	54·52	55·44
Non-Amino ..	2·07	1·61	1·79	2·29
TOTAL ..	101·53	100·13	100·34	99·80

Conarachin

	Local		Spanish	
Preparation No ..	I	II	I	II
Method .	Dialysis	Salt Saturation	Dialysis	Salt Saturation
Melanin, insol.	0·88	1·05	1·36	1·04
Melanin, adsorbed by lime . ..	0·97	0·69	0·98	1·22
Amide .. .	11·92	12·16	11·14	11·12
Basic—				
Arginine . .	21·87	22·37	23·20	22·76
Histidine	3·01	3·33	3·17	2·89
Lysine .. .	5·80	5·26	4·57	5·11
Cystine .. .	0·93	1·01	1·04	0·98
Non-Basic—				
Amino	51·95	52·02	54·42	53·40
Non-Amino	0·99	1·33	1·62	2·10
TOTAL .	98·29	99·21	101·50	101·62

TABLE IV

(*In per cent of Protein*)

Amino Acid	Total Globulins			Arachin			Conarachin		
	Local	Spanish	Virginian	Local	Spanish	Virginian	Local	Spanish	Virginian
Arginine	13·68	13·26		13·96	13·55		14·10	13·07	
Histidine	1·67	1·58		1·92	1·95	1·88	1·99	1·88	1·83
Lysine	4·49	4·69		4·35	4·41	4·98	4·82	4·97	6·04
Cystine	1·24	1·42		1·17	1·17	0·85*	1·57	1·64	
Tyrosine	5·48	4·80		5·69	5·43	5·50†	3·09	3·23	
Tryptophane	0·58	0·66		0·66	0·69	Present	0·93	1·07	

* Method of Van Slyke (1911)

† Method of Folin and Denis (1912)

Local and Spanish varieties—Authors

Virginian variety—Johns and Jones (1916–18)

From the above table the following points may be noted Compared with Arachin, Conarachin is characterised by its higher contents of basic nitrogen, cystine, tryptophane and lysine. But it is, however, much poorer in tyrosine. On the whole, the proteins of the three varieties of groundnuts—Local and Spanish, grown in India and Virginian grown in America—do not show any appreciable difference in their composition Perhaps the methods of analysis are not sufficiently sensitive to show the subtle varietal differences which may possibly exist.

TABLE V

Amino Acids	1 Groundnut Cake	2 Milk	3 Soyabean	4 Gram
Arginine .. .	13·26	4·84	5·12	11·85
Histidine . ..	1·58	2·59	1·39	1·42
Lysine . ..	4·69	5·95	2·71	7·42
Cystine .	1·42	1·20	?	2·02
Tyrosine . .	4·80	4·50	1·86	2·95
Tryptophane .	0·66	1·50	?	0·46

1 Spanish variety, Total Globulins—Authors.
2 and 3 'Soyabean'—Piper and Morse (1923).
4 Niyogi, *et al*, 1932.

In the above table, the total globulins of groundnut are compared with the total proteins of milk, of soyabean and of gram (*Cicer arietinum*) Groundnut protein is characterised by its higher content of tyrosine and arginine—two of the most important essential amino acids Though slightly poor in lysine content, it is better than soya-bean protein. In its histidine content, groundnut protein is quite comparable to the proteins of soyabeans and *Cicer arietinum*

Since milk proteins are considered to be perfect and complete, an approximate value of other proteins in animal nutrition may be obtained by comparing their compositions with that of milk proteins The table clearly points to the conclusion that the proteins of groundnut compare more favourably with milk proteins than those of soyabeans. Thus as revealed by chemical analysis, groundnut proteins are, in some respects, superior to soyabean proteins

Daniel and Loughlin (1918) have conducted feeding experiments with groundnut cake According to them the proteins of groundnut are comparable to those of soyabean Both these legumes supply the essential amino-acids in sufficient amounts for normal growth and reproduction Groundnuts are lacking in the fat soluble accessory, but contain a considerable amount of the water-soluble vitamins Rats fed on a mixture of groundnut meal furnishing 18 per cent of protein, 5 per cent of butter fat, lard and corn starch to which no minerals were added, grew normally, reproduced and successfully reared their young Again, Wallis (1917) also states that groundnut contains a very complete protein (*cf* Press Note of the Industries Department of the Bombay Government, 1918) Groundnut cake, milk powder and sodium bicarbonate mixed in the proportions of 94 5 . 1, yield a very good invalid food Such a mixture has been successfully used for the preparation of culture media. Mixed with egg white, it can be used as a diabetic food Wheat flour when mixed with groundnut cake in the proportion of 3 1 is said to make as ideal a bread as possible and can be used for the preparation of " Rotis " Johns and Finks (1920) have made similar observations Bread made from 25 parts groundnut flour and 75 parts wheat flour furnished adequate proteins for normal growth Proteins of this bread were utilised twice as well as those of bread made of wheat only.

Further, groundnut is easily available in this country where it has become native for a long time and its method of cultivation is well known to the farmers. It can be grown even under dry-farming conditions in sandy soil It can be eaten raw or cooked and can be introduced into the daily diet of the masses without much difficulty As regards the keeping quality of groundnut cake, Sahasrabuddhe and Bhatt (1935, private communication) have shown that it can be kept for a long time if the flakes of the fresh-cake are heated to 100° C and placed in airtight containers

On the other hand, soyabean is an exotic to this country and is only now being introduced It cannot be digested raw and has to be cooked under pressure Soyabean flour prepared in the ordinary way does not keep well and gets rancid easily A well-keeping flour can be prepared by patented methods only which are not in the easy reach of poor cultivators The bean possesses a slight bitterness for which a taste must be cultivated Its flour when added to bread to improve the colour of the crumb has been found to destroy the Vitamin A content of the bread Similar tests with cod-liver oil have shown that soya flour destroys nearly the whole of the

Vitamin A of the oil (*Scientific American*, February 1937, p 104). Recently Dr W R Aykroyd, Director of Nutrition Research, Indian Research Fund Association, addressing the Rotary Club of Calcutta, struck a note of warning against the extended use of soyabean which is now being popularised In his opinion, it remained to be shown by conclusive experiments whether the soyabean had any particular advantage over the common pulses (*Times of India*, December 5, 1936).

From the above it will be seen that groundnut is in no way inferior to soyabean In some respects it has certain advantages over the latter. It is therefore advisable to investigate fully the possibilities of the easily available groundnut before advocating the use of soyabean in India.

The authors are greatly indebted to Rao Bahadur Dr. D L. Sahasrabuddhe for his keen interest and advice during the course of this investigation

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ON SOME NEW FORMS OF BATRACHIA FROM S. INDIA.

By C R Narayan Rao

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The material which forms the subject of this paper has been collected during the excursions of the members of the Staff and students of the Department of Zoology, University of Mysore, for over six years The primary object of these excursions has been to study the distribution of anuran fauna in the localities explored, their mode of occurrence and their general habits We selected certain types of areas marked by distinctive physical features, and the results of our collections and of the field observations are set forth in these notes

The Malnad areas of Kadur, Hassan and Shimoga Districts of Mysore, the Anamalai Hills of Coimbatore and Perambikulam forests of Cochin were selected for making collections, and for purposes of comparison, specimens were also taken from the plains The chain of hills separating Mysore from Malabar and North and South Canara forms a definite landmark and well-wooded gigantic spurs, divided by innumerable water courses, extend on either side The base of these elevated regions is clothed with dense vegetation and harbours pools formed by waterfalls The soil is composed almost entirely of laterite, and there are places in the Malnad where rich loam and stiff clay are also encountered During the monsoon these areas receive abundance of rain which inundates the country swelling the small mountain streams into torrents and converting the shallow puddles into dangerous pools Perambikulam is in the heart of Cochin forests and the summit of the hills are covered by grass, being elevated above the forest belt Below the hills are covered by bamboos and forest trees which abound in big game Anamalai Hills are clothed by impenetrable forests and even the base of the Hills could only be approached with difficulty. On account of scanty rainfall in the lower regions, the ground is hard and water scarce During the hot weather all these areas become parched and they seem scarcely to harbour any life The most favourable time for collection of batrachian specimens is sometime after the rains, when cryptozoic forms will not have retreated into their burrows, but will be found lurking near about the water margins

The distribution and occurrence of batrachian fauna in the Maidan, semi-Malnad areas and the ghats which present striking physical features, present a sharp contrast The main point of interest is that each of these areas is inhabited by groups which hardly extend into the adjacent territory For instance, typical Maidan forms like *R. hexadactyla*, *R tigrina*, *R limnocharis* and *R breviceps* are not encountered in the ghats and the only exception is *R. cyanophlyctis* which can be taken in the thickest forest and on the tops of the highest peaks. *Bufo melanostictus* follows *R cyanophlyctis* in its occurrence; but *Bufo fergusoni* does not extend beyond the semi-Malnad area into the ghats Again *Rhacophorus maculatus* is strictly an inhabitant of the plains and is rarely met with in the ghats, though a few specimens of this species have been collected from the semi-Malnad areas We can scarcely draw a line of demarcation between strictly Malnad and semi-Malnad in regard to the distribution of forms such as *Rana curtipes*, *Rana malabarica*, *R leptodactyla*, *R aurantiaca*, *R dobsoni*, *R verrucosa*, *R rufescens*, *R beddomii* and similarly with regard to *Rhacophorus malabaricus*, *Rh lateralis* and *Bufo pulcher*, *Bufo microtympanum*, *B parietalis* When we enter the forests which clothe the sides of the hills, we discover that these forms are replaced by a bewildering wealth of batrachian life belonging to the genera *Ixalus* (*Philautus*) and *Micrixalus* and *Nyctibatrachus*, and *R cyanophlyctis* and *Bufo melanostictus*, however, freely mingling with them Except for a few stray forms of *Ixalus* and *Micrixalus* occasionally found in the semi-Malnad areas, the three genera *Ixalus* and *Micrixalus* and *Nyctibatrachus* may be described as inhabitants of mountain slopes, but they rarely extend to the summits where only *R. cyanophlyctis* and *Bufo melanostictus* occur

Among the *Engystomatidæ*, the most hardy creature is *Microhyla ornata*, which in point of distribution follows *R cyanophlyctis* and *Bufo melanostictus*, though it may not be found on the summit of the hills *Cacopus* (*Euperodon*) *systoma*, *M rubra*, *Callula* (*Ramanella*) *variegata*, *C* (*R*) *triangularis* and *C* (*R*) *obscura* are strictly confined to the plains. But the semi-Malnad zone in Mysore harbours a race of *Callula* (*Ramanella*) whose adaptive modifications to the peculiarities of the environment affected by them, differ so strikingly from their congeners in the plains, that one would be justified in creating a separate genus for the reception of these forms They are all as a rule short legged, the tibio-tarsal articulation hardly extending beyond the middle of the body, and they have no web, and all possess the power of climbing the smooth surfaces of the plantain trees Our collection of Engystomatid forms from the plain districts is sufficiently rich and varied and a comparison of the semi-Malnad specimens with them indicates the lines along which divergence has proceeded It is to be noted that none of these Engystomatidæ are met with in the thickly wooded places on the slopes of hills, and their favourite haunt is the cordamom plantation and plantain gardens behind the village houses of the Malnad areas

The hill slopes which receive an annual rainfall of over 200 inches, are cut up by mountain torrents during the monsoon, but become dry and parched during the hot weather The Batrachians [*Ixalus* (*Philautus*), *Micrixalus* and a few members of *Rhacophorus* and *Nyctibatrachus*] affecting these slopes, are scarcely met with in water, but are always found clinging to the rocks, loose stones and tree trunks in the close vicinity of waterfalls, running brooks and sheltered pools They have large digital expansions, and excessively long hind limbs and slender bodies (the only exception being *Nyctibatrachus*), enabling them to cling to hard surfaces when their homes are flooded, or to swim against the rapid current *R cyanophlyctis* is a thoroughly aquatic form, but it has a habit of burrowing in sands under water and also of skimming over the surfaces of water by taking a series of short leaps, enabling the frog to escape being carried away by the floods *B melanostictus* is capable of burrowing or entering narrow crevices and fissures of rocks, where they abide till the disturbances of weather are over In consequence of these peculiar habits of life, they do not seem to have developed any anatomical peculiarities different from the other members of their tribe living in the plains Both these forms are known to traverse fairly long distances and it is this habit which has brought them to the Malnad areas and hill tracts

The larvæ of some species of *Ixalus* in our collection almost as a rule have greatly enlarged lips, which, we have noticed, they use in adhering to rocks and water weeds They are sufficiently large to act as floats in case the tadpoles are caught in the rapids It is well known that the tadpoles of *Nyctibatrachus* possess widely expanded lips which are suctorial. In the case of *R. cyanophlyctis* and *Bufo melanostictus*, the tadpoles have powerful caudal fins, far more powerfully developed than in the forms found in the plains and their pouting lips are provided with enlarged beaks and teeth As a rule, they attain a larger size, far larger than tadpoles of corresponding age in the plains In the semi Malnad belt, where a large number of species of *Rana Rhacophorus* and *Bufo* occur, their larvæ differ in the degree of development of fin, size of tail and in the mouth parts, which, while affording diagnostic characters, are nevertheless features due mainly to adaptive modifications I have had occasion to study the larval forms of anura taken from all these areas, and I am of opinion that, while those coming from similar situations present fairly uniform characteristics capable of being used for taxonomic purposes, on the other hand, specimens of tadpoles belonging to the same species, but taken from situations differing widely in regard to the condition of the country and rainfall, show corresponding differences in external morphology. I shall refer below to a few instances of such divergent modifications and point out how the mouth parts alone, such as the beaks and horny denticles, are not affected by the change of environment and how they can be used for the purpose of relating the tadpoles to their parents on the basis of these characteristics Appropriate comments on the tadpoles will be made under the respective heads

In the descriptive part, I have followed the nomenclature introduced by Parker, Boulenger and Malcolm Smith

Recently, a number of emended schemes of classification of the group *Anura* have been put forward, based upon osteological characters The family engystomatidæ under the changed nomenclature is treated as Microhylidæ by H W Parker[1] and the names of the Indian genera formerly included in the group have also undergone alteration Thus Cacopus becomes *Uperodon*—*Callula* is now recognised as *Ramanella*, while *Microhyla* and *Melanobatrachus* are permitted to retain their names unaffected In S India, the family Microhylidæ is chiefly represensed by the following four genera (1) *Uperodon*, (2) *Ramanella*, (3) *Microhyla* and (4) *Melanobatrachus* As the first two names are not quite familiar yet and as it is not widely understood what they replace, I have used the names still in common use in the introduction and in the systematic description, I have adopted the new nomenclature Similarly with regard to *Ixalus*

In 1920, Boulenger[2] revised the genus *Rana*, making use of several characters neglected for a long time and he pointed out that the recognition of their value for taxonomic purposes might lead to a better understanding of their inter-relationships He has divided the genus *Rana* into 9 sub-genera of which species belonging to sub-genera *Rana*, *Tomopterna*, *Discodeles* and *Hylorana* are represented in South India

In 1930, Dr Maclolm Smith[3] pointed out that, as the name *Ixalus* was preoccupied, this genus should in accordance with the accepted terms of nomenclature be known as *Philautus* and he does not favour the fusion of this genus with *Rhacophorus* whose generic position is still left intact He retains the name *Rhacophorus* in preference to *Polypedates*

In the following descriptive accounts, I have used the names suggested by these authors

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[1] "Frogs of the Family Microhylidæ," H. W. Parker, B.A., *British Mus Nat. Hist.*, 1934.

[2] "A Monograph of the South Asian, Papuan, Melanesian and Australian Frogs of the Genus *Rana*," G. A. Boulenger, *Rec Ind Mus*, Vol. XX, June 1920.

[3] "The Reptilia and Amphibia of Malaya Peninsula," Malcolm A. Smith, *Bull. Raffles Museum, Singapore*, 1930.

Genus RANA

Sub-Genus TOMOPTERNA

Rana parambikulamana n sp

Vomerine teeth in short oblique series, commencing from the inner angle of the choanæ which are transverse, oval and directed inwards The hinder margin of the vomerine teeth, extending far beyond the posterior border of the choanæ Tongue without a median papillæ The lower jaw with three tooth-like conical prominences

Head convex, distinctly longer than broad, snout pointed, projecting beyond the lower jaw, longer than the eye, canthus rostralis obtuse, loreal region slightly oblique, concave, nostril nearer to eye than to the tip of the snout, distance between the nostrils greater than the interorbital width which is 2/3 that of the upper eye-lid, tympanum indistinct, 2/5 the diameter of the eye, equal to its distance from the eye

Fingers rather short, obtuse, first nearly equal to the 2nd, both considerably shorter than the third which is distinctly longer than the snout The first finger with a larger basal pad, subarticular tubercles prominent, rounded, fourth digit equals the diameter of the eye

Hind limb long, the tibio-tarsal articulation reaching far beyond the tip of the snout, the heels crossing when the limbs are folded at right angles to the body, tibia more than three times as long as broad and 2 and 1/6 times in the length from snout to vent, slightly longer than the fore limb and longer than tarsus, fourth toe considerably longer than the thigh or tibia and slightly more than twice the length of the tarsus All the toes are long, obtuse, ¼ webbed, outer metatarsals united, subarticular tubercles small, not conspicuous, inner metatarsal tubercle large smaller than the first toe, inserted almost in line with the latter, outer metatarsal tubercle inconspicuous

Skin smooth above and on the ventral surface, a fold from the hinder angle of the eye, extending over the tympanum to the shoulder, two short prominent folds from behind the eye directed slightly inwards, and a pair of less conspicuous folds on either side of the dorsal band, also starting from the upper margin of the eyelids, two short obliquely set folds forming an open ∩-shaped space on the back behind the shoulder as in *R verrucosa* and *R rufescens* No granulation on any part of the body

Yellowish brown above, deeper over the head and the shoulder, with a light vertebral band; cutaneous folds edged black, a broad white band from the eye to shoulder beneath the fold, lips with alternate light and dark bands; sides of body and ventral surface white; limbs barred, the stripes of the thighs oblique

Male with two large vocal sacs, black confluent medially

A single specimen. Type in the Central College Museum

Habitat —Parambikulam forests, Cochin State, S India.

MEASUREMENTS.

	mm.		mm.
From snout to vent	39 00	Fore arm	8·00
Head	15 00	Arm	9·00
Width of head	11 50	First finger	6·00
Snout	6 50	Second finger	5·75
Eye	5 00	Third finger	2·50
Upper eyelid	3 00	Fourth finger	5·00
Interorbital width	2 00	Thigh	16·50
		Width of thigh	8·00
Distance between eye and nostril	2 50	Tibia	18·00
		Width of tibia	5 00
Distance between nostril and tip of snout	3 00	First toe	5 00
Distance between nostrils	3 00	Second toe	9 00
		Third toe	15 50
Distance between eye and tympanum	2 00	Fourth toe	23·50
Tympanum	2·00	Fifth toe	14 00
Internarial distance	3·00	Inner metatarsal tubercle	3·00

I have compared this specimen with R *rufescens*, *R breviceps* and *R dobsoni*, from which it differs almost in every character, and generally resembles *R tigrina* in external form, though differing in details both from this species and *R limnocharis* (Forma typica) through which this new species is derivable

Rana leucorhynchus, n sp

Vomerine teeth in strong oblique series, separated only by a narrow median gap in the median line, but well separated from the choana The choana are oval orifices, transversely situated. Behind the vomerine teeth, a well-marked broad triangular palatine cavity Tongue without a median papillæ, lower jaw with a single tooth-like prominence

Head narrowly concave, slightly longer than broad; snout obtuse, truncated, projecting beyond the mouth, very slightly longer than the eye; canthus rostralis angular, loreal region oblique, broadly concave, nostril slightly nearer the tip of the snout than the eye, distance between the nostrils equals the inter-orbital width, upper eye lid ⅔ in the distance between the eyes; tympanum distinct, smaller than the diameter of the eye, 3½ times its distance from the latter

Fingers rather long, pointed, first longer than the second, shorter than the third which is longer than the snout ; the first exactly equals the snout and twice the width of the upper eyelid Subarticular tubercles large and conical , tubercular pads at the base of the first and third finger

Hind limbs short, the tibio-tarsal articulation reaching the eye, the heel separated when the limbs are folded at right angles to the body , tibia just as long as the thigh , length of tibia more than 3 times in the length of thigh, more than 2 times in its length , width of thigh equals the length of the snout and the latter 1⅓ times the width of tibia The length of the hind limb (without digits) exceeds very slightly the distance between the snout and vent Tarsus two times the width of tibia , toes rather short, ⅓ webbed, outer metatarsals united , subarticular tubercles small, inconspicuous , an inner tarsal fold present, inner metatarsal tubercle large, strongly, compressed with a sharp edge, as long as the first toe, at the base of which it is obliquely set A small outer metatarsal tubercle at the base of the fourth toe

Dorsal surface of the body, throat and chest smooth , abdomen and sides of the body and lower surface and posterior margin of thighs granular , sides of body with interrupted folds , no fold from eye to the shoulder

Pale brown above ; upper surface of snout including the anterior third of the upper eyelid with a distinct broad white band Between the eyes a dark W-shaped band , behind the eyes and shoulders white ; proceeding from behind the eyes, a long oval brown mark with a pair of darker streaks running along the median line of the area A similar mark ∩-shaped in the median line of the back, and U-shaped marks on the sides of the body and hip , fore arms and legs cross barred , throat and abdomen white , under-surface of thighs yellow ; loreal region with a dark broad band from the eye to the snout , below the eye a dark anvil-like mark, the lower lid being white , foot chocolate brown

MEASUREMENTS

	mm.		mm.
Snout to vent	35·00	Arm	7·00
Head	16 50	First finger	6 00
Width of head	15 00	Second finger	5·00
Snout	6·00	Third finger	7·50
Eye	5 50	Fourth finger	4·75
Distance between eye and nostril	2 50	Thigh	13·50
		Tibia	13·50
Distance between nostril and snout	3 00	Tarsus	8·00
		Width of thigh	6·00
Distance between nostrils	4·00	Width of tibia	4·00

	mm.		mm.
Distance between eye and tympanum ..	1·00	Inner metatarsal tubercle ..	3·50
Interorbital width	4 00	First toe ..	3·50
Upper eyelid . .	3 00	Second toe . ..	6·00
Tympanum .. .	3 50	Third toe	10·00
Fore arm . .	7 25	Fourth toe	14 00
		Fifth toe .. .	8 50

Toes ⅓ webbed

(Linked with *Rana tigrina* through var *pantherina* resembling *R cancrivora* at least superficially)

Habitat —Wattakole, Coorg, South India

A single specimen

Type —Central College, Bangalore

Sub-Genus HYLORANA

Rana intermedius, n sp

Vomerine teeth in short oblique groups, arising far from choana, the distance between them and the latter is greater than the median gap separating the series of teeth The internal bulging of the eyes into the mouth forms two large massive structures almost meeting in the median line posterior to the vomerine teeth Tongue very large and broad, without a papillæ

Head strongly depressed, much longer than its width , snout acutely pointed, projecting well beyond the mouth, far longer than the diameter of the eye , canthus rostralis very distinct, loreal region nearly horizontal, deeply concave , nostril nearer to the tip of the snout than the eye ; distance between the nostrils equal to the interorbital width , upper eyelid four-fifths in the distance between the eyes , tympanum (that on the right side is larger than the left) very distinct , smaller than the eye, separated from the latter by a distance equal to ¼ or ⅓ its own diameter

Fingers rather slender, terminating in discs , first longer than the second , third slightly longer than the snout , subarticular tubercles fairly large, round , a distinct horse-shoe shapped groove separating the upper half of the disc from the lower

Hind limb rather long , tibio-tarsal articulation reaching the nostrils, heels completely overlapping when the legs are folded at right angles to the body , tibia nearly five times as long as broad and more than half the total length of the body, very greatly exceeding the fore limb , toes moderately long, the tips dilated into discs, all bearing more or less well defined grooves, discs broader than long, web extending to the tips of all the toes except the fourth and fifth, subarticular tubercles conical, not conspicuous, outer metatarsal tubercle 2/5 in the length of the first toe, a small conical outer metatarsal tubercle at the base of the fourth toe

Skin smooth, a narrow dorso-lateral glandular fold from the eye to the groin, no fold from the eye to the tympanum to the shoulder, the distance between the dorso-lateral folds across the iliac bones is more than 1/5 in the total length of the body, humeral gland No parotoids

Uniform brown above, sides darker, limbs faintly cross-barred, abdomen and throat with irregular dark areas, under surface of thighs yellowish, posterior and anterior border of the thighs mottled

Habitat—Saklespur, Hassan District, Mysore State

Type—Central College, Bangalore

The species is intermediate between *R gracilis* and *R temporalis*, both of which occur in the same locality with *R malabarica*, *R aurantiaca* and *R curtipes* I have compared this with these members in almost every particular and I am convinced that though it resembles with one or the other of these species in certain characters, it is entitled to the rank of a separate species This course is justifiable when the size and proportions of the head, the relative size of the tympanum and the eye are taken into account

MEASUREMENTS.

	mm.		mm
Snout to vent	43·00	First finger	7 00
Head	20 00	Second finger	6·00
Width of head	13 50	Third finger	9 00
Snout	8 50	Fourth finger	7 50
From nostril to tip of snout	4·00	Thigh	20 00
Tympanum	4 00	Width of thigh	5 00
Eye	6 50	Inner metatarsal tubercle	2 00
From eye to nostril	4 75	Tarsus	12 00
Internarial width	5 00	Width of tarsus	3 00
Interorbital width	5 00	First toe	5 00
Upper eyelid	4 00	Second toe	8 50
Distance between tympanum and eye	1 00	Third toe	13 50
Arm	9·00	Fourth toe	20 00
Fore arm	8 25	Fifth toe	15 00

Rana sauriceps, n sp

Vomerine teeth in short oblique series, arising from the anterior border of the choanæ which are horizontal and extending slightly beyond the hinder border of the latter Lower jaw with a small median and two lateral median tooth-like prominences. Tongue very small, without a papilla

Head somewhat elongated, convex, longer than broad ; snout acutely pointed, truncated projecting beyond the mouth, twice as long as the diameter of the eye, with a triangular or diamond-shaped pit on the terminal dorsal aspect Behind this rostral pit there are two oval elevations with a median transverse groove and both separated from a similar elevation between the eyes These elevations look not unlike the cephalic shields of the Saurians , behind the tip of the snout there is a pit on each side, separated by a ventral bar from the loreal region which is almost horizontal and concave , canthus rostralis obtuse , nostrils nearer to the snout than to the eye , distance between the nostrils equal to the interorbital width , tympanum slightly smaller than the eye, the latter is twice the distance between it and the former and this distance is equal to the upper eyelid

Fingers moderate, obtuse without discs , first finger equal to the second, about ⅔ in the length of the snout , third as long as the snout , the fourth longer than the first or second and is equal to the arm Subarticular tubercles conical, moderate

Hind limbs rather long, slender, tibio-tarsal articulation reaching the nostril , heels very slightly overlapping when the legs are folded at right angles to the axis of the body , thigh nearly twice its width , tibia three times its width, but considerably less than half the total length of the body and slightly shorter than the third toe equal to the fifth , toes pointed , web not extending to the tip of the first phalangeal bone, rather stopping at the base , outer metatarsals not united, separated by web, inner metatarsal tubercle about ½ the diameter of the eye , a small rounded outer metatarsal tubercle at the base of the fourth toe ; subarticular tubercles small, inconspicuous

Upper surface of the skin slightly granulate, with short interrupted longitudinal folds with a few tubercles , curved temporal fold is present , in preserved specimens, the abdomen is thrown into fine transverse folds ; throat, abdomen and undersurface of the thighs free from granulation. No dorso-lateral glandular fold. A ∩-shaped mark found on the back behind the shoulders

Above chocolate red, sides darker, fore arm and tarsus faintly barred ; throat and chest yellowish, abdomen brown, the under surface of the thighs pale orange ; upper lip with vertical bands, two of which enter the eye , the lower lip with dark and white spots or bars

MEASUREMENTS.

	mm.		mm.
Snout to vent	30·00	Third finger . ..	6·00
Tympanum	2·50	Fourth finger . .	5·00
Eye	3·00	Thigh	10·50
Distance between eye and tympanum	1·50	Width of thigh ..	5·00
Head	10·50	Tibia . .	12·00
Width of head .	8·75	Width of tibia . .	4·00
Snout	6·00	Tarsus .	9·00
From nostril to snout .	2·25	Width of tarsus .	3·00
From eye to nostril	3·00	Inner metatarsal tubercle..	1·50
Interorbital width	3·75	First toe .	4·00
Upper eyelid . ..	1·50	Second toe .	8·00
Fore arm . .	6·50	Third toe . ..	11·00
Arm	5·00	Fourth toe .	15·00
First finger . .	4·00	Fifth toe . .	10·00
Second finger	4·00	Outer metatarsal tubercle	0·75

Habitat —Wattekole, Coorg, S India

A number of specimens of all ages

Type —Central College, Bangalore

Sub-Genus DISCODELES.

Rana tenuilingua n sp

Vomerine teeth in short, transverse or slightly oblique series, arising separately from the choanæ, almost on a level with the posterior border of the latter , the space between the rows exceeds the distance between the teeth and the choanæ , tongue very thin, small, the posterior notch sometimes very broad, a small conical retractile papilla in the middle ; the lower jaw is covered by the upper throughout and the maxillary teeth are large, without tooth-like prominence on the lower jaw

Head broadly convex, slightly wider than long ; snout obtuse projecting beyond the mouth, as long as or slightly longer than the eye , canthus rostralis obtuse ; loreal region oblique concave , nostril nearer to the tip of the snout than the eye ; interorbital width more than twice the distance between the nostrils and is equal to the upper eyelid , tympanum ⅔ in the diameter of the eye and twice the distance between it and the latter , the fronto-parietal region is excavated into a flask-like depression, occasionally traversed by a median groove and this area is further separated by a transverse groove from the nasal region where the fold of skin is elevated into scale-like patches separated by a median groove corresponding with the bony sutures. The nasal "scales" are divided from the premaxillary area by a transverse groove, with a ridge of skin in front, connecting the nostrils The markings on the head are exactly like those of *Rana saurıceps* but without the rostral pit

Fingers are short, tips dilated into truncated discs which are broader than long, the groove in front of the discs is either absent or faintly marked in some, first finger as long as or very slightly longer than the second, third slightly longer than the snout, subarticular tubercles very faintly visisble

Hind limb long, tibio-tarsal articulation reaching nostril or tip of snout, the heels strongly overlap when the limbs are folded at right angles to the body, tibia about 5 times as long as broad, thigh half in the length of the body from snout to vent and longer than the fore limb, toes rather short, discs truncated, broader than long, the groove indistinct, web extending to nearly three-fourths of the first phalanx of fourth toe and second of fifth and third, web not extending to the base of the outer metatarsals, subarticular tubercles inconspicuous, inner metatarsal tubercle feebly developed, a very small outer metatarsal tubercle at the base of the fourth toe Phalanges T-shaped

Upper surface of skin with a series of interrupted fine folds, about 6 to 7 longitudinal series can be made out, throat and chest and undersurface of thighs smooth, abdomen finely granulate No temporal fold

Pale brown above, sides darker, upper surface of snout white; a dark band from the tip of the snout extending through the loreal region, and below the eyes, surrounds the tympanum, a short dark band from the tympanum to the shoulder, lower jaw with dark and white longitudinal bars, fore arm and fingers and hind limbs barred, throat pale yellow, abdomen white, undersurface of thighs reddish

MEASUREMENTS

	mm		mm
From snout to vent	23 00	First finger .	2 25
Tympanum	2 00	Second finger .	2 00
Eye .	3 00	Third finger . ..	4 00
		Fourth finger .. .	2 50
Distance between tympanum and eye	1 00	Thigh ..	11 00
Snout .	3 50	Width of thigh . ..	3 50
		Tibia	13 50
Distance between eye and nostril	2 25	Width of tibia .	2 50
		Tarsus .	7 50
Distance between nostril and snout .	1 25	Width of tarsus ..	1 50
Distance between nostrils .	2 75	Inner metatarsal tubercle .	1 00
Distance between eyes .	3 00	First toe .	2 50
Upper eyelid .. .	1 25	Second toe .. .	5 00

	mm.		mm.
Head . .	9 00	Third toe .	7 50
Width of head ..	9 25	Fourth toe .	12 0
Fore limb : Arm .	4 75	Fifth toe .	7 00
Fore arm .	4 75	Outer metatarsal tubercle	

Habitat --Kemphole Ghats, Hassan, Mysore, South India

Type —Central College, Bangalore

Genus NYCTIBATRACHUS

Nyctibatrachus sylvaticus, n sp

Vomerine teeth in two oblique rows, short series set well behind the choanæ

Head as long as broad or slightly longer, depressed, projecting beyond the mouth Snout not longer than the diameter of the eye Inter-orbital space equals the width of the upper eyelid Eyes lateral Distance between the eye and the nostril equals 2½ times the internarial width Tympanum partially or completely hidden Supra tympanic fold present Habit not stout Canthus rostralis angular, well marked Loreal region concave, oblique Fingers dilated into small discs First finger shorter than second Third longer than snout Subarticular tubercules moderately large, not very prominent

Hind limbs long The tibio-tarsal articulation reaching the posterior angle of the eye Heels touch when the limbs are folded at right angles to the body Thigh more than 1½ times longer than its width and tibia more than three times its width, and less than half in the length of the body Toes with tips swollen into small discs, more than half-webbed Sub-articular tubercles moderately developed Inner metatarsal tubercle elongate, spade-like, more than half the length of the first-toe, connected by web to the base of the first toe No outer metatarsal tubercle

Skin above with tubercles and short glandular folds Thighs free Tibia, tarsus and fifth toe distinctly granular Arms feebly granular Lower surface including the limbs perfectly smooth

Brown above Both limbs with faint cross bars Ventral surface including the limbs whitish Lower jaw with feeble white bars on a pale background of brown

MEASUREMENTS.

	mm		mm.
Diameter of the eye	4·00	**Fourth finger** .	6 75
Snout	6 00	**Thigh** . . .	17 75
Interorbital space ..	4·00	**Thigh thickness** .. .	10 00
Upper eyelid . ..	4·00	**Shank**	19 00

	mm.		mm.
Internarial width	2·00	Shank thickness	6·50
Distance between eye and nostril	5·00	Tarsus	11 00
Arm	6 75	Tarsus thickness	3·50
Arm thickness	3 50	First toe	5 00
Fore arm	8 75	Second toe	8·00
Fore arm thickness	4·00	Third toe	12 00
First finger	5 00	Fourth toe	17 00
Second finger	6 00	Fifth toe	12 00
Third finger	8 00	Inner metatarsal tubercle	2 75
		Total length	42·00

Habitat —Forests of Kempholey, Saklespur, Hassan, Mysore

Type —Central College, Bangalore

Remarks —There are three species of *Nyctibatrachus* known, *viz*, *N pygamæus*, *N major* and *N sanctipalustris*, of which we have a fairly good collection The new species differs from the known forms in certain fundamental respects and might even appear as a connecting link with *Rana* For instance, the tympanum is only partially hidden, the eyes are laterally directed and the body is not stout and a canthus rostralis is present With the exception of these characteristics, its resemblance to the other species of *Nyctibatrachus* is fairly intimate. The configuration of the body and limbs of this species may perhaps be an expression of convergence towards the *Ixalus* type, evoked by the peculiar mode of life and the character of the surroundings

Genus NANNOBATRACHUS

According to Boulenger this genus is distinguished from *Nannophrys* by the character of the pupil which is vertical in *Nannobatrachus* and horizontal in *Nannophrys* To this difference he adds a few other factors which make the two genera sufficiently distinctive The species with which the following notes deal, possesses a horizontal pupil more or less red even in the preserved state and agrees with the other characteristics of *Nannobatrachus*. The pupil of the eye in the living specimen bears no resemblance to its shape in the preserved forms, undergoing some amount of distortion on account of contraction. This is rather an uncertain character for the purpose of differentiating genera, and even as a specific character it is not reliable No importance is attached to this character in these notes I have not examined *Nannophrys* and am therefore unable to suggest how far we may depend upon characters like the outer metatarsals being united at the base or separated by grooves for separating *Nannophrys* from *Nannobatra-*

Boulenger has described only two species of the former and one of the latter and for purposes of the example described below, I shall adopt his classification

Nannobatrachus kempholeyensis, n sp

Pupil red, horizontal, habit fairly stout, toad-like Vomerine teeth in two short series almost transverse arising from the anterior border of the choanae, with a wide gap between, which is nearly twice as wide as the series of the teeth Tongue moderate, nicked deeply behind, bearing in front a large spherical elevation, clearly marked off from the rest of the tongue and surrounded by a pit, whether a retractile papilla is present is doubtful. Lower jaw without a tooth-like projection

Head flat, wider than longer, snout rounded, scarcely projecting beyond the mouth, as long as the interorbital width or twice the diameter of the eye; canthus rostralis indistinct, loreal region either nearly vertical or slightly oblique, concave in the latter case, nostril equidistant between the eye and the tip of the snout, distance between the nostrils [illegible] in the interorbital width, upper eyelid equal to the distance between the nostrils or the diameter of the eye, tympanum indistinct or absent

Fingers rather small, first obtuse, second, third and fourth with ends dilated at the tips into spherical balls not very distinct from the ultimate phalangeal bone; first finger slightly smaller than the second, subarticular tubercles distinct on the third and the fourth fingers only

Hind limb short, the tibio-tarsal articulation not reaching quite the eye but only its posterior border, the heels do not meet when the limbs are folded at right angles to the body, thigh as long as the fourth toe and less than twice its own length, tibia more than twice the length of the snout and slightly exceeds the width of the head, tarsus quite as long as the thigh and more than twice its own width, tips of toes dilated into small discs, not distinct on the first, discs as long as broad, second toe very slightly exceeds the length of the first; subarticular tubercles indistinct, inner metatarsal tubercle very minute and the outer at the base of the fourth toe still more minute; no rudiment of web No tarsal fold Outer metatarsals separated by grooves

Skin smooth or slightly granulate behind the eyes and shoulders; no folds on the back or sides in the living forms (preserved specimens show them on the sides due to shrinkage), a short temporal fold only occasionally present on one side and in that case extending beyond the shoulder Abdomen and lower surface of thighs finely granulate

Upper parts of the body and limbs deep bronze or black uniformly; in the males throat is yellowish, in the females the throat and abdomen and undersurface of thighs very finely marbled, hand white; foot darker; the red eyes in the living forms are very bright and conspicuous

Males with internal vocal sacs united into a comparatively large structure extending to the breast

Omosternum and sternum cartilaginous and slender terminal phalangeal bones of toes slightly expanded, nasal bones relatively wide, separated from one another and from the fronto-parietals by narrow grooves

MEASUREMENTS.

	mm		mm
Snout to vent	18 00	First finger	1 50
Head . .	6 00	Second finger . ..	2 00
Width of head	7 00	Third finger .. .	3 50
Snout	3 00	Fourth finger . ..	3 00
Distance between nostrils and tip of snout	1 50	Thigh	5·00
		Tibia ..	7 75
Distance between eye and tip of snout	1 50	Width of thigh ..	3 00
		Width of tibia .. .	2 00
Internasal width .	2 00	Tarsus .	5 00
Interorbital width	3 00	Width of tarsus . ..	2 00
Tympanum .		First toe ..	1 50
Eye .. .	2 00	Second toe .	1 75
Upper eyelid .. .	2 00	Third toe .	3·00
Fore limb Fore arm	4 50	Fourth toe	5 00
Arm .	3 00	Fifth toe . ..	4·00

Habitat.—Hills of Kempholey Ghats, Hassan, Mysore, S India Four specimens

Type.—Central College, Bangalore

The frogs were found under the rocks near waterfalls and they are incapable of burrowing Nothing is known about their breeding habits

This species may be distinguished from *N beddomii* thus —

1 Tibio-tarsal articulation reaching the tip of the snout or not quite so far; limbs barred, white below immaculate, tongue without an elevated button-like structure in front .. . *N beddomii*

2 Tibio-tarsal not reaching the eye, limbs without bars, beneath finely marbled; tongue with a button-like structure in front . *N kempholeyensis*

Genus BUFO.

Bufo brevirostris, n sp.

Crown without bony ridges Habit stout. Head perfectly flat, broader than long; snout rounded, not projecting bevond the mouth, as long as the eye; canthus rostralis angular; loreal region horizontal, broadly concave, nostril nearer to the end of the snout than to the eye, distance between the nostrils ⅔ in the distance between the eyes, upper eyelid slightly shorter than the interorbital width, tympanum small, fully developed, ⅔ the diameter of the eye, distance between the eye and the tympanum ½ the diameter of the latter or ⅓ the diameter of the former

Fore limb very short; fingers short, rather slightly swollen at the extremity; first equal to the second, third as long as the arm and fourth not longer than the first or the second; subarticular tubercles feebly developed. The tubercle at the base of the third finger is much larger than that at the base of the first.

Parotoids elongate, moderately prominent, as long as the arm, slightly more than twice its own width

Hind limb short, the tibio-tarsal articulation not reaching the shoulder, the heels just touch when the limbs are folded at right angles to the body, thigh nearly as long as wide; tibia about 2⅔ as long as broad and 1½ times longer than the tarsus; toes very short, tips rather obtuse, entirely free, subarticular tubercles not prominent, inner metatarsal tubercle about ½ in the length of the first toe, the outer much smaller situated at the base of the fifth toe

Upper surface of the skin covered with small uniformly distributed tubercles; with a small row of larger warts on the median line of the back, the first pair being the largest; throat and abdomen with spiny granules which are more prominent on the limbs A dark temporal line extending to the sides.

Pale brown above, with a network of dark lines, sides lighter with similar marbling, ventral surface dirty white with dark blotches; undersurface of thighs white.

MEASUREMENTS.

	mm.		mm.
Snout to vent	27·00	Fore arm	7·00
Eye	3 00	First finger	3·00
Tympanum	2 00	Second finger	3·00
Parotoids	4·50	Third finger	4 50
Width of Parotoids	2·00	Fourth finger	3·00

	mm.		mm.
Head	8 00	Thigh	5·00
Width of head	9 00	Width of thigh	
Snout	3 00	Tibia	8·00
Interorbital width	3 00	Width of tibia	3 00
Upper eyelid	2 50	Tarsus	6 00
		Width of tarsus	2·25
Distance between eye and tympanum	1 00	Inner metatarsal tubercle	1 00
		Outer metatarsal tubercle	
Distance between eye and nostril	2 00	First toe	3·00
		Second toe	4·00
Distance between eye and snout	1·00	Third toe	5 75
Distance between nostrils	2 00	Fourth toe	8 00
Arm	4 50	Fifth toe	5 00

Habitat—Kempholey, Hassan District, Mysore State

A single specimen

Type—Central College, Bangalore

Genus PHILAUTUS

Dr Malcolm Smith in describing some specimens of ***Philautus*** (***Ixalus***) from the Malay Peninsula observes that "it is now generally recognised that the presence or absence of vomerine teeth can no longer be regarded as a character of generic distinction Although fully accepting this principle, I am not in agreement with those authors who have hastily sunk all the species of ***Philautus*** under ***Rhacophorus*** That some forms of ***Philautus*** should be placed under ***Rhacophorus*** is no doubt correct, but the distinctive habit of many other species, suggests that characters will yet be found to retain them apart from ***Rhacophorus*** Until a proper revision of the whole group is taken, I prefer to retain the two genera as defined by Boulenger." Now the revision was undertaken by my colleague Mr L S Ramaswami who in reviewing the osteology of the two genera, comes to the conclusion that "after a perusal of the characters enumerated in the résumé (which embraces 21 points) it will be noticed that ***Rhacophorus*** and ***Philautus*** agree with each other in seven of the minor features referred to above It is, therefore, expedient at the present state of our knowledge to treat ***Rhacophorus*** and ***Philautus*** as two independent genera." I have myself examined the morphological characters of the several forms of both genera and I have no hesitation in accepting the conclusion of Mr Ramaswami that ***Rhacophorus*** and ***Philautus*** should be treated as separate genera which is in accordance with the suggestion of Dr Malcolm Smith. But I am not quite sure if the diagnostic features given by Boulenger of ***Philautus*** are adequate and whether they do not overlap with those of *Micrixalus* Omitting the common features, the only characters in the definition of the two genera, as given by Boulenger, separating them are the presence (*Philautus*) or absence (*Micrixalus*) of an intercalary ossification between the penultimate and distal phalanges and the latter being obtuse in *Philautus* and T-shaped in *Micrixalus* In other respects the differences do not seem so fundamental as to justify the retention of the two genera as distinct entities and the forms of *Micrixalus* in our collection are too few to suggest the fusion of *Philautus* and *Micrixalus* If the behaviour patterns of the Batrachians afford an indication, as is assumed by Noble, of phyletic relationships, then nothing can be easier than to bring *Micrixalus* under *Philautus*, for our observations on the breeding habits and on the larval forms of the members of these two genera point to a close agreement But we know that arguments based on this correspondence may be used as a factor only in emphasising the evidence derived from other sources, but they alone cannot constitute a testimony sufficient to favour the merging of one genus into another In this paper I retain the generic rank of *Philautus* and *Micrixalus*

Philautus charius, n sp

Vomerine teeth none Papillæ on the tongue absent

Snout acutely pointed as long as the diameter of the eye Canthus rostralis distinct Loreal region concave, strongly obliquely disposed Nostrils nearer to the tip of the snout than to the eye Distance between eye and nostrils equals half the interorbital width Interorbital space twice as broad as the upper eyelid and broader than the diameter of the eye Tympanum distinct, about one-third the diameter of the eye, and separated from it by half its own diameter. Internarial width half the interorbital space, equals the distance between the eye and the nostril Fingers not long; tips provided with discs with a narrow crescentic groove separating the dorsal and ventral portions First finger smaller than the second, slightly less than half the length of the third Subarticular tubercles moderately developed

Hind limbs long, the tibio-tarsal articulation reaches the nostril, the heels touch when the limbs are folded at right angles to the body. Thigh less than half in the total length of the body. Tibia nearly as long as the thigh, and more than three times as long as broad Metatarsus considerably more than half the length of the tibia Toes rather short, tips dilated into discs, one-third to half-webbed Metatarsals united Subarticular tubercles feebly developed, a very minute inner metatarsal tubercle present No tarsal fold.

Upper surface of the skin finely granulate, the granules confined to the dark median portion, sides smooth Granules occur on the upper eyelid and on the dorsal portion of the snout. No dorso-lateral glandular fold. Throat smooth, chest and abdomen finely granulate. A supra temporal fold present.

Upper surface of the snout and sides of the body bright yellow (pale in spirit). A dark hour glass-shaped mark starting between the eyes and covering the hinder half of the eyelid, occupies the back extending nearly to the vent A conspicuous chevron-shaped dark marking on the vent Canthus and loreal region and upper jaw dark brown. Lower jaw with white and dark dots and vertical lines Between the eye and the shoulder a deep black mark, covering the tympanum, the lower border of which bears a white crescentic line Fore arm banded Third and fourth fingers bear dark stripes and the upper surface of the discs of these digits having dots Upper surface of thighs with cross bars, the posterior border bronzed with faint white spots Tibia with stripes, which are inconspicuous on the metatarsus Heel bears a dark black spot, from which a dark line runs down to more than half the distance of the last two toes, whose upper surface is striped and the top of the discs of all toes faintly dotted The throat, belly and undersurface of thighs and arms white

This specimen of *Philautus* is named after my colleague Mr. B. R. Seshachar who has collected a large number of South Indian Batrachians.

MEASUREMENTS.

	mm.		mm.
From snout to vent ..	23·00	Width of fore arm ..	2·00
Diameter of the eye .	3·00	First finger . .	2·25
Upper eyelid ..	2·00	Second finger . ..	3·00
Interorbital space ..	4·00	Third finger	5·00
		Fourth finger ..	4·00
Distance between eye and nostril .	2·00	Thigh	10·50
Internarial distance ..	2·00	Width of thigh	3·50
Tympanum ..	1·00	Tibium	11·00
		Width of tibium	3·00
Distance between eye and tympanum	0·50	Metatarsus	7·00
Head	8·50	Width of metatarsus ..	1·75
Width of head .. .	9·00	First toe	2·00
Snout	3·50	Second toe	3·00
Arm	4·00	Third toe	5·00
Width of arm . ..	1·50	Fourth toe	6·50
Fore arm	5·00	Fifth toe	5·00

Locality—Kottigehar, Kadur.

Type.—Central College, Bangalore

Philautus elegans, n sp

Vomerine teeth none A small papilla on the anterior portion of the tongue, retracted into the sheath. Head flat, longer than broad Snout elongate, sharply rounded anteriorly, bevelled, projecting beyond the mouth. Canthus rostralis distinct, strongly angular Loreal region concave, horizontal. Nostrils nearer to the eye than the snout Distance between the nostrils slightly more than the interorbital space Upper eyelid equals or slightly less than the interorbital space. Tympanum distinct, half the diameter of the eye, closely touching it

First finger slightly shorter than the second, third longer than the snout Subarticular tubercles fully developed. A shallow groove separates the dorsal and ventral portions of the discs

Hind limb rather moderately long, the tibio-tarsal articulation reaching the eye Heels touch each other when the limbs are folded at right angles to the body Thigh two and a half times as long as broad and less than half the length of the body Tibium slightly longer than thigh and is just half the length of the body and slightly less than three times its breadth Metatarsus about three times as long as broad Toes rather short, end in discs, about less than half-webbed Outer metatarsals united at the base, bearing an outer fold of skin Subarticular tubercles feebly developed A small outer metatarsal tubercle

Skin with minute wart-like tubercles disposed longitudinally on the back, or perfectly smooth A supra-temporal fold absent Dorso-lateral glandular fold, feebly developed, extending from the posterior angle of the eye to the groin The two are separated by a space nearly $\frac{1}{4}$ in length of the body Lower parts of the limbs and body smooth Small glandular swellings behind the jaws and in front of shoulder

Crimson above. A concave dark streak between the eyelids Sides of body commencing from behind the eyes black Tympanum red. Loreal region faintly bronzed. The posterior border of upper jaw white Lower jaw with a few black dots. Posterior border of the fore arm vermiculated Posterior limbs with dark bands Posterior border of thighs with white spots on a black background. The cross bars extend to the metatarsus Last two toes with dark bands. Upper surface of discs dark. Throat and chest marbled. belly yellow (white in spirit) Thighs pinkish

This is the prettiest specimen in the collection.

MEASUREMENTS.

	mm		mm.
From snout to vent	23 0	Width of fore arm	1·75
Head	9 00	First finger	3·00
Width of head	7 00	Second finger	3 50
Diameter of the eye	3 00	Third finger	4·75
Upper eyelid	2 00	Fourth finger	3·50
Interorbital space	2 50	Thigh	10 00
Snout	3 75	Width of thigh	4 00
Distance between eye and nostril		Tibium	11 50
	2 00	Width of tibium	3 00
Internarial width	2 75	Metatarsus	6 00
Tympanum	1 50	Width of metatarsus	2·00
Distance between tympanum and eye		First toe	4 00
	Nil	Second toe	5·00
Arm	6 00	Third toe	7·00
Width of the arm	1 75	Fourth toe	9 00
Fore arm	6 00	Fifth toe	7 00

Locality —Kempholey, Hassan

Type —Central College, Bangalore

Philautus kottigeharensis, n sp.

Vomerine teeth none Tongue with a papilla, the sac with tumid lips

Head depressed Upper surface of the snout deeply concave, bounded by ridges anteriorly and laterally Tip of snout acutely pointed, broader truncated, and projecting beyond the mouth Snout longer than the eye Canthus rostralis prominent and angular Loreal region concave, oblique, becoming continuous with the suborbital grooves. Nostrils prominent, equidistant between tip of snout and eye Internarial width equals the diameter of the eye Interorbital width less than the upper eyelid Tympanum fairly distinct, about half the diameter of the eye, which it closely touches

Fingers tipped with large discs, about twice as broad as the penultimate phalangeal segment First finger slightly longer than the second and the third very slightly longer than the snout All the fingers are free Subarticular tubercles feebly developed.

Hind limbs long. Thigh more than twice as long as broad and as long as the tibium Tibio-tarsal articulation reaches tip of the snout Metatarsus longer than arm and more than twice as long as broad Toes rather short, tip ending in discs, web extending to the discs. Outer metatarsals united at the base or separate Subarticular tubercles feebly developed, a very minute inner metatarsal tubercle

Upper surface of body with minute tubercles, a supra-temporal fold and dorso-lateral folds are present The latter commence well behind the eyes, and are separated from each other by a distance less than 1/5 in the total length of the body Deep suborbital grooves confluent with the loreal region present. Undersurface of body and thighs smooth

Uniform deep bronze above and sides of head, body and limbs, hind limbs and fore arms barred by deeper stripes Discs of fingers and toes dark on both surfaces Web dark, and the folded toes produce a characteristic deep black colour Lower jaw and throat bronzed—the dark colour extending sometimes to the chest and the anterior division of the abdomen, or the latter two regions may be bright orange, ventral undersurface of thighs red, the posterior border feebly marbled Sides of body yellowish or whitish

MEASUREMENTS

	mm.		mm
From snout to vent	23 00	Width of fore arm	2 00
Head	8 00	First finger	3 00
Width of head	6 00	Second finger	3 50
Snout	4·00	Third finger	4 75
Eye	3 00	Fourth finger	4 00
Upper eyelid	2 00	Thigh	15 00
Interorbital space	2·00	Width of thigh	4 50
Tympanum	1 50	Tibium	15 00
Distance between tympanum and eye		Width of tibium	3·00
	Nil	Metatarsus	8 00
Distance between eye and nostril		Width of metatarsus	2 25
	2·00	First toe	3 25
Internarial distance	3 00	Second toe	5 00
Arm	7 00	Third toe	7 75
Width of arm	2 00	Fourth toe	11 00
Fore arm	5 00	Fifth toe	8 00

Locality—Kottigehar, Kadur

Type—Central College, Bangalore

Philautus swamianus, n sp

Vomerine teeth none. Tongue large, bifid behind, a conical papillæ nearer to the anterior end, retractile sheath an elongated slit

Head perfectly flat, depressed, snout pointed, projecting beyond the mouth, longer than the eye Canthus rostralis prominent, angular Loreal region concave, horizontal, separated from the narrow suborbital or upper narial groove. Nostrils prominent, about midway between the eye and the tip of the snout. Distance between nostrils very slightly less than interorbital space, equals diameter of the eye. Interorbital space wider than the upper eyelid, and exceeds the eye by a narrow margin Tympanum half hidden, and about half the diameter of the eye from it is separated by a a distance less than its width.

Tips of fingers with discs, nearly twice as broad as the penultimate phalangeal segment There is no groove separtaing the dorsal and ventral portions of the discs First finger shorter than the second, the former about the diameter of the eye. The third slightly exceeds the length of the snout. Subarticular tubercles feebly developed on the first and the second fingers and absent from the third and the fourth fingers

Hind limb fairly long, the tibio-tarsal articulation reaching beyond the eye, heels overlap when the limbs are folded at right angles to the body. Thigh 2¼ times as long as broad and tibia about as long as thigh and slightly less than 3½ times its width Toes rather short, web extending to the discs which are equal to twice the width of the penultimate phalangeal segment Subarticular tubercles poorly developed. A small inner conical metatarsal tubercle present Outer metatarsals separated at the base. No tarsal fold. Heels prominent

Skin smooth above and also below Supra-temporal fold inconspicuous Darso-lateral folds occur, starting from behind the eyes and separated from each other by a space equal to the interorbital width Folds may be interrupted, not quite reaching the groin In addition there are two fairly well-developed lateral folds, converging towards the vent, beginning from about the middle of the sides of the body. The two sets of folds may become continuous

Upper surface of the body uniformally bluish, dark bronze in spirit. Loreal region and upper jaw lighter Thighs and tibia barred. Fore limbs without bands. On the sides of the body, commencing from the eyes, are fine rows, two or three, of white glandular bodies which meet in front of the vent Throat pale buff, chest marbled, abdomen white Anterior portion of the ventral surface of thighs pinkish, the posterior vermiculated Undersurface of tarsus, foot and discs bronzed.

I have named this species after my colleague Mr. L. S. Ramaswami, whose contributions to our knowledge of the cranial morphology of the Anura of South India have been of invaluable assistance to me.

MEASUREMENTS.

	mm
From snout to vent	29 00
Head	10 00
Width of head	8 00
Eye	3·00
Upper eyelid	2 00
Interorbital space	3 50
Distance between eye and nostrils	2·00
Snout	4 00
Internarial space	3 00
Tympanum	1 50
Distance between eye and tympanum	1 00
Arm	6 00
Width of arm	2·00
Fore arm	5 50

	mm.
Width of fore arm	2 00
First finger	3 00
Second finger	3 50
Third finger	5·00
Fourth finger	4·00
Thigh	15·00
Width of the thigh	6·00
Tibium	15 00
Width of tibium	4 50
Tarsus	6 00
Width of metatarsus	2 25
First toe	3 00
Second toe	5 00
Third toe	6 50
Fourth toe	8 50
Fifth toe	6 50

Locality.—Kottigehar, Kadur

Type—Central College, Bangalore

Philautus melanensis, n sp.

No vomerine teeth Mouth large. Tongue comparatively small, a short conical papillæ on the anterior half of the tongue Lower jaw with a small anterior median tooth-like prominence, with deep indents on each side

Head rather large, depressed nearly as broad as long, or only slightly longer. Snout blunt, rounded anteriorly, a little longer than the eye, projecting slightly beyond the mouth Canthus rostralis prominent, broad angular. Loreal region concave, nearly horizontal or slightly oblique, continuous with the suborbital groove Diameter of the eye equals the width of the upper eyelid Interorbital distance greater than the eye Nostrils nearer the tip of snout than the eye, internarial space about half or only slightly less than half the length of the snout. Tympanum distinct, about two-thirds in the diameter of the eye, which it almost touches or may be separated by a line.

Fingers with discs which are about twice as broad as the penultimate phalangeal segment. A distinct crescentic groove separates the dorsal and ventral parts. First finger shorter than the second and the third twice as long as the first or twice the diameter of the eye. Fourth finger equals or very slightly longer than the snout Subarticular tubercles well developed

Hind limbs rather long, the tibio-tarsal articulation reaching the tip of the snout or beyond Heels overlap when the limbs are folded at right angles to the body Thigh less than four times its own width and is shorter than tibium Tibium more than four times its own width First three toes free, a rudimentary web at the base of the fourth and fifth toes Discs as broad as the penultimate phalangeal segment Subarticular tubercles poorly developed Outer metatarsals united at the base An inner metatarsal tubercle in an extremely rudimentary condition No outer metatarsal tubercle No tarsal and metatarsal folds

Upper surface of skin with or without short longitudinal folds covered uniformly with fine white granules These granules extend to the thighs and sometimes to the tibia A supra-tympanic fold Throat, chest, belly and undersurface of limbs and toes covered with large tubercles

Uniform black above Anterior limbs black Thighs and tibia either black or pale yellow with cross bars Ventral surface of body and thighs yellowish Undersurface of tibia and foot, black or bronze

MEASUREMENTS.

	mm		mm.
From snout to vent	29·00	Width of fore arm	3·00
Head	13·00	First finger	3·00
Width of head	12·00	Second finger	4·00
Eye	3·00	Third finger	6·00
Upper eyelid	3·00	Fourth finger	4·50
Interorbital space	5·00	Thigh	15·00
Distance between eye and nostril	3·50	Width of thigh	4·00
Snout	4·00	Tibium	17·00
Internarial distance	2·50	Width of tibium	4·00
Tympanum	2·00	Tarsus	9·00
Space between eye and tympanum	Nil	Width of tarsus	3·00
Arm	8·00	First toe	3·00
Width of arm	3·00	Second toe	4·50
Fore arm	8·00	Third toe	8·00
		Fourth toe	12·00
		Fifth toe	8·25

Locality.—Kempholey, Hassan.

Type—Central College, Bangalore

Philautus narainensis, n sp

No vomerine teeth, tongue small, thin, leaf-like with a conical papilla, retractile sheath slit-like Mouth rather small Choana broadly separated, situated at the extreme lateral margin

Head depressed longer than broad, snout acutely pointed, the prenasal region acutely triangular viewed from above In front, the snout bears pits and grooves, the latter vertically disposed, the tip of snout looking like a prostomeal lobe Snout projects beyond the mouth, a conspicuous glandular mental pad Canthus rostralis prominent, ridge-like and angular Loreal region concave, horizontal, confluent with the anterior rostral pits in front and suborbital groove behind Upper surface of the internarial region concave, bounded anteriorly by a transverse bar of the prostomial lobe ; eye 1⅓ times the upper eyelid which equals the interorbital space Snout longer than the eye and the nostrils about midway between the eye and tip of the snout Internarial space wider than the interorbital width and equals the diameter of the eye Tympanum moderately distinct, about ⅓ the diameter of the eye from which it is narrowly separated

Fingers rather short with discs which are small on the first and the second, larger on the fourth which is twice as wide as the penultimate phalangeal segment First finger shorter than the second The fourth finger a little longer than the eye A single subarticular tubercle on the first finger, others nearly free Grooves of the discs not clear

Hind limb rather long, the tibio-tarsal articulation reaching beyond the tip of the snout Heels overlap when the limbs are folded at right angles to the axis of the body Thigh more than three times as long as wide, tibia longer than the thigh and about 5 times as long as broad Toes rather short, discs small. Web extending upto the discs of first two toes, but stops at the base of the penultimate phalangeal bone of the fourth toe, and at the base of the phalangeal bone of the third and the fifth Outer metatarsal free at base Subarticular tubercle feebly developed No inner or outer metatarsal tubercle Heel not marked, no dermal appendage No tarsal and metatarsal folds

Skin smooth above and below No supra-temporal fold The place of dorso-lateral folds is taken by two short folds commencing from behind the eyes, terminate on the back, a little behind the shoulder, about 1½ times as long as the snout, and separated from each other by a space equal to the interorbital width

Brownish red above including the limbs The anterior border of the thighs and the upper part of tibia very feebly banded The posterior border of thighs and the inner border of tibia feebly vermiculated Throat and chest buff coloured Belly dirty white. Lower surface of thighs and the tibia whitish

This species is named after my colleague Mr A Narayana Rao, who has added considerably to our batrachian collection.

MEASUREMENTS

	mm.
From snout to vent	29 00
Head	10 00
Width of head	7·50
Diameter of the eye	3 00
Upper eyelid	2·00
Interorbital space	2 00
Snout	4 00
Distance between eye and nostril	2 00
Internarial space	3 00
Tympanum	1·50
Distance between tympanum and eye	0 50
Arm	7 00
Width of arm	2·00
Fore arm	5·00

	mm.
Width of fore arm	2·00
First finger	2·00
Second finger	3·25
Third finger (Injured in both arms)	
Fourth finger	3·50
Thigh	13 00
Width of thigh	4 00
Tibium	15 00
Width of tibium	3·00
Tarsus	6·25
Width of tarsus	2 00
First toe	3·00
Second toe	5·00
Third toe	8 00
Fourth toe	10·75
Fifth toe	8·00

Locality —Kottigehar, Kadur

Type —Central College, Bangalore.

Philautus longicrus, n sp.

Vomerine teeth none Tongue without papilla. Choana laterally situated Head moderately depressed, as long as broad Snout obtusely pointed, a little longer than the eye, scarcely projecting beyond the mouth Canthus rostralis prominent Loreal region slightly concave and horizontal Nostrils midway between the eye and the tip of the snout Distance between the nostrils equals the diameter of the eye or the interorbital space Upper eyelid about $\frac{3}{4}$ in the interorbital space Tympanum distinct, about half the diameter of the eye, being separated from it very narrowly

Fingers moderately developed Discs not broad, slightly wider than the terminal phalangeal segment First finger shorter than the second. Subarticular tubercles fairly well developed. Length of arm equals the length of the snout

Hind limb very long The tibio-tarsal articulation reaching far beyond the tip of the snout Heels strongly overlap when the limbs are folded at right angles to the body. Tibium more than four times as long as broad and is longer than the thigh. Tips of toes dilated into discs, half-webbed.

Outer metatarsals united at the base A minute elongate inner metatarsal tubercle. Subarticular tubercles fairly well-developed A faint outer metatarsal fold. No tarsal fold

Upper surface of the skin with faint folds Sides with short glandular folds, serially arranged Minute tubercles occurring between the series Ventral surface of body and thighs smooth Upper surface of snout pale grey—a dark band between the nostril and eye over canthus rostralis Loreal and suborbital region yellow, extending as far behind as the angles of the mouth. A brown mark over the supra-tympanic fold Tympanum reddish Upper and lower jaw with dark vertical bands, the upper series terminating just below the middle of the eye Interorbital space with a faint transverse band Upper surface of body olive brown Thighs with cross bars on the anterior border, the posterior border minutely marbled Tibium also barred anteriorly, but whitish posteriorly A dark line stretching from heel to foot Lower surface of the body and thighs white

MEASUREMENTS.

	mm.		mm
From snout to vent	20·00	Width of fore arm	3 00
Head	8·50	First finger	2 75
Width of head	8·50	Second finger	3 00
Snout	4 00	Third finger	3 75
Eye	3·00	Fourth finger	2 50
Upper eyelid	2·00	Thigh	10 00
Interorbital space	3 00	Width of thigh	4·00
		Tibium	13 00
Distance between eye and nostril	2 00	Width of tibium	3·00
Internarial distance	3·00	Tarsus	6 25
Tympanum	1 50	Width of tarsus	2 00
		First toe	2 00
Distance between tympanum and eye	0·75	Second toe	4 00
Arm	4·00	Third toe	6·00
Width of arm	2 00	Fourth toe	10·00
Fore arm	5 00	Fifth toe	5·50

Locality.—Kempholey, Hassan

Type —Central College, Bangalore.

Philautus montanus, n sp

Vomerine teeth absent. Tongue with a short papilla situated rather anteriorily and in the spirit specimen retracted into a pit, strongly bifid.

Head depressed as long as broad. Snout rounded, broadly truncate, not projecting beyond the mouth. Snout longer than the eye Canthus rostralis vertical, loreal region concave and horizontal Nostrils nearer to the tip of snout than to eye Internarial distance equals the space between the eye and the nostrils. Diameter of the eye equals the interorbital width and is more than twice the tympanum Upper eyelid less than interorbital space Tympanum not prominent, about half the diameter of the eye from which it is separated by a narrow space

Fingers moderately long, tips provided with discs bearing the groove separating the upper from the lower portion No web Discs small, smaller than the tympanum. First finger shorter than the second Third finger longer than the snout Subarticular tubercles moderately developed.

Hind limb long; the tibio-tarsal articulation reaching the eye Heels do not overlap when the limbs are folded at right angles to the body Thigh more than three times its width, tibium as long as the thigh and more than four times its own width Metatarsus equals or slightly longer than the third or fifth toe Toes not long, about two-thirds webbed Discs smaller than those of the fingers A small oval inner metatarsal tubercle present Base of toes united, outer metatarsal without a fold No outer metatarsal tubercle Subarticular tubercles moderately developed

Skin smooth above Throat, chest and abdomen and undersurface of the arms and hand finely granulate A feebly developed supra tympanic fold present A faintly V-shaped fold of skin on the occiput, commencing from the middle of the eyelids No dorso-lateral fold

Bright red above in the living condition, brownish red in spirit, with or without white spots on the body Throat and upper part of chest brownish, speckled with white Rest of the ventral surface yellowish, the dark bands meeting on the anterior border of thighs give rise to ocellus-like spots when viewed ventrally A brown band between the eye-lids, faint in spirit Thighs barred, a single broad band on the shank Undersurface of hind limbs yellow with brown marbling

MEASUREMENTS.

	mm		mm
From snout to vent	37 00	Width of arm	3·00
Head	14 00	Width of fore arm	2 75
Width of head	14 00	First finger	3 25
Internarial distance	3 00	Second finger	4 50
Distance between eye and nostirl	3·00	Third finger	7·50
		Fourth finger	6·25
Eye	5·00	Thigh	17·00
Nostril	6 00	Width of thigh	5 00
Interorbital width	5·00	Shank	17 00
Upper eyelid	3·00	Width of shank	4·00

	mm		mm.
Tympanum	2 50	First toe	3 50
Distance between tympanum and eye	1 00	Second toe	5 00
Arm	6 00	Third toe	9 00
Fore arm	8 00	Fourth toe	12 00
		Fifth toe	9 00

Locality —Hills of Kempholey, Hassan

Type —Central College, Bangalore

Family MICROHYLIDAE

Ramanella minor, n sp

Post-narial ridges strongly developed, obliquely set, meeting dorsally, with an extremely narrow ventral cleft. Anterior pharyngeal fold inconspicuous Snout short, broadly truncated Distance between nostrils equals width of the upper eyelid Interorbital space nearly twice the width of the upper eyelid Diameter of the eye less than the length of the snout Canthus rostalis obtuse Loreal region almost vertical Distance between eye and nostril equals the diameter of the eye

Tibio-tarsal articulation touches middle of the body Toes entirely free, tips almost pointed Subarticular tubercles well-developed Inner metatarsal tubercle conical, moderately developed Outer metatarsal tubercle rounded, inconspicuous When the hind limbs are folded at right angles to the body, the heels touch

Fingers with triangular dilations, nearly twice as broad as the penultimate joint

Skin smooth above, slightly pustular on the sides A fold from the posterior angle of the eye to the shoulder No occipital fold Lower surface smooth.

Upper surface of snout olive, with a median dark band, short not reaching the interorbital space Sides of the snout dark which is continuous with the dark on the sides and ventral surface of the body. A dark spot between the eyes on the upper surface of the head A dark broad band on the dorsum, flanked by olive bands The latter do not extend to the sides of the body The former stops at the coccyx, which is olive mottled, with dark irregular markings The anterior and posterior limbs entirely black. The ventral surface including the throat black The abdominal region and thighs bearing white spots.

MEASUREMENTS.

L.—25 mm.

Diameter of the eye	2·00	Third toe	6·50
Length of snout	2·75	Fourth toe	9·00
Distance between the nostrils	1·50	Fifth toe	6·00
Interorbital width		Thigh across the anterior border	7·00
Distance between eye and nostril	2·00	Thigh across the anterior border ventrally	9·00
First toe	2·00	Shank	9·75
Second toe	4·00	Tarsus	5·50

Locality.—Saklespur, Hassan

Type.—Central College, Bangalore

Ramanella triangularis rufeventris, n. var.

In the plantain gardens behind the houses in Saklespur, there is a small variety of R. *triangularis*, occurring fairly in large numbers. These are found in the whorls of the leaf stalks, and are mostly solitary. This variety possesses the power of climbing smooth surfaces like *R. variegata*.

This variety differs from the *R. triangularis* in two characteristics

1. The snout is pointed, tips obliquely truncated, prominent.
2. Tibio-tarsal articulation stands well behind the shoulder.

In regard to colour, almost every specimen in the collection bears an occipital dark band continuous at the sides with the tympanoloreal band. This cross band may or may not be continuous with the dorso-median band. Even in the spirit specimens, the lower surface is reddish (in the living state, the red is bright and warm) which extends over the undersurface of the anterior and posterior limbs. The ventral white spots are confined to the abdomen and the lower surface of thighs. A short dark streak on the rostrum is always present. The olive is replaced in this variety by grey. Limbs barred with dark red.

Ramanella triangularis of the plains is not met with in the Malnad areas and it is represented by this local variety which may be designated *Ramanella triangularis rufuventris*.

Length 22 mm. Specimens, Central College, Bangalore.

Locality.—Mudigere, Kadur, Saklespur, Hassan.

Ramanella mormorata, n sp

Post-choanal ridges transversely disposed, well developed, a broad median gap between the two ridges The anterior pharyngeal ridge strongly arched, the limbs dilated into thick lateral swellings The fimbriæ of the posterior pharyngeal ridges not conspicuous Snout short, truncated, not prominent, as long as the diameter of the eye Canthus rostralis rounded Loreal region oblique Rostralis rounded Inter-orbital space much broader than the upper eyelid which equals the internarial distance

Fingers with wide triangular dilations, which are twice as large as the penultimate joints

Toes ending obtusely, with a suspicion of a web at the base, sub-articular tubercles moderately developed Inner metatarsal tubercle shovel shaped Outer metatarsal tubercle well developed, conical, situated at the base of the fifth toe Tibio-tarsal articulation does not reach the shoulder, but stands well behind the axilla Heels stand apart when the hind limbs are flexed behind at right angles to the body Skin on the upper surface is warty in the young specimens, tubercles becoming confined to the posterior half of the body, sometimes extending to the dorsal surface of the hind limbs in the mature forms Lower surface perfectly smooth Supra tympanic fold inconspicuous. No occipital fold

Immature specimens pale olive or pale reddish brown above Mature males bright reddish brown above, mature females deep olive above A dark broad band between the eyes, sometimes involving the lids Snout bearing a triangular or V-shaped dark mark A broad angular dark band between the shoulders Behind this region, dark spots or irregular markings invariably occur which may sometimes extend to the sides No lateral dark bands on the body Loreal region free Limbs bright yellow or deep olive green according to the sex The posterior border of the arm bears a dark band Fore arm, hand, fingers, thigh, shank, tarsus, foot and toes barred The crural band usually extending into the groin, may be reduced to a spot continuous with the prevailing colour of the upper surface Lower surface including the throat and the limbs beautifully marked in the male with yellow and reddish brown and in the female with dark blue and moss green

MEASUREMENTS

	mm		mm.
Diameter of the eye .	3 00	Thigh	7 00
Distance between eye and nostril .	2 75	Width of thigh .	5 00
		Shank .	9 00
Snout .	3 00	Width of shank ..	.. 3 00

Internarial distance	2·00	Tarsus	4·00
Interorbital space	3·75	Width of tarsus	2·00
Upper eyelid	2·00	Width of foot	3·00
Upper arm	4·00	First toe	2·00
Fore arm	6·00	Second toe	4·25
First finger	2·50	Third toe	6·00
Second finger	3·00	Fourth toe	8·50
Third finger	5·00	Fifth toe	6·00
Fourth finger	4·25	Total length	25·00

Locality.—Saklespur, Hassan District, Mysore

Type.—Central College, Bangalore

Remarks.—The specimens were found in the whorls of the plantain leaves. They usually occur solitary. Occasionally two or three specimens may be found together in the same cramped space.

Ramanella anamalaiensis, n. sp.

Post-narial ridges incompletely developed, that on the right-side is absent. Post-pharyngeal ridge fimbriated. Snout broadly triangular, truncated. Head depressed. Diameter of the eye greater than the length of the snout. Interorbital space twice the width of the upper eyelid. Distance between the eye and nostril equals width of upper eyelid. Internarial distance slightly more than half the length of the snout. Canthus rostralis rounded. Loreal region oblique. Supra-tympanic fold present. No occipital fold. Tips of fingers truncated, not discoidal, about the same width as the penultimate joints. Fore arm slightly longer than the third finger and twice as long as the first. Toes perfectly free, ending obtudely. Thigh slightly shorter than the third toe, shank shorter than the fourth toe. Shank more than twice as long as wide. Inner metatarsal tubercle moderately developed, shovel shaped. Outer obtusely conical placed between the bases of the fourth and fifth toes. Sub-articular tubercles moderately developed. Tibio-tarsal articulation reaches the shoulder. Heels do not touch when the legs are folded behind the vent at right angles to the body.

Upper surface of the skin warty. Lower surface smooth. Bright olive above with a broad dark median band commencing from behind the occipital region and extending upto the coccygeal region, behind this band a few irregularly shaped black-markings. Bewteen the eyes a squarish dark mark and on each upper eyelid a dark spot. Upper surface of the snout olive. Loreal region and sides of body reddish brown. Upper surface of arms olive blotched with brown. Fore arm reddish brown. Upper surface of thighs and shanks reddish brown, throat and abdomen and lower surface of limbs pale brown. A few indistinct white spots on the belly Hand and foot brown

MEASUREMENTS

	mm		mm
Diameter of the eye .	4 00	Shank . Length	9 50
Snout	3 00	Width .	4 00
Interorbital space ..	4 25	Tarsus Length .	6 00
Upper eyelid . .	2 00	Width	3 00
Distance between nostrils	1 75	First toe .	2 00
Distance between eye and nostril . .	2 00	Second toe .. .	4 50
Arm .	6 00	Third toe	7 75
Fore arm ..	8 00	Fourth toe .	11·0
First finger .	4 00	Fifth toe	6 50
Second finger	5 00	Broadest part of the foot (between 2nd and 5th toes)	4 00
Third finger	7 50	Total length .	28 00
Fourth finger .	5 50		
Thigh · Length	7 25		
Width	5 50		

Locality —Base of Anamalai Hills, Coimbatore District

Type —Central College, Bangalore

TADPOLES

Philautus leucorhincus

These tadpoles are small Head and body rather narrowly oval Upper surface convex, ventral rather flat The snout is rounded and slopes down Diameter of the mouth smaller than the convex interorbital space, which is as wide as the internasal breadth Nostrils nearer to the eyes than to the tip of snout Eyes and nostrils dorso-lateral Spiracular tube short, not prominent Spiracular orifice directed upwards and backwards nearer to the eye than to the root of the hind limbs Mouth disc provided with upper and lower lips The latter is notched in the middle Both lips and lateral lobate borders fringed with papillæ The upper beak with a smooth border, the lower with a serrated margin No teeth The tail is long The upper fin commences far beyond the root of the tail, and is stringly arched The ventral fin commences well behind the dorsal and has a straight border The dorsal fin is deeper Tip of tail pointed The limbless forms have an yellow dorso-median area, which in the preorbital region becomes white which is characteristic mark of the adult Sometimes a brown dorsal band Sides and belly blackish. Throat whitish, muscular part of the tail yellowish with black marks. In the four-legged forms, the colour becomes uniformly rufous, the snout remaining whitish. The dark dorsal band becomes more marked. Anal tube dextral.

MEASUREMENTS.

	mm		mm.
Total length .	. 26 00	Breadth of body	.. 5·50
Length of head and body	9 00	Depth of body .	. 4 00
Length of tail .	. 17 00	Depth of tail ..	.. 3 75

Locality.—Streams of Kempholey, Hassan.

Philautus hypomelas

These tadpoles have an elongated body, and are not large. The head and body are elliptical. Snout broadly rounded, mouth ventral. Hind end of body more or less tapering. Both surfaces of body convex. Mouth small, shorter than the interorbital space. Internasal width slightly greater than the interorbital breadth. Eyes and nostrils dorso-lateral. Spiracle broad at the base, directed upwards, orifice dorso-lateral, nearer to the eye than to the root of the hind limb. Mouth disc small, provided with well-developed upper and lower lips. The latter multilobed. The lower lip and the lobate sides are free from papillæ which occur only on the upper lip. The inner border of the lower lip with a crenulate edge. The upper beak is smooth, the lower serrated. No teeth. The tail is well developed. The upper fin begins well behind the root of the tail. Both fins are of equal depth and are broadly curved. Tip of tail pointed. Skin smooth. Upper surface of the body purplish or reddish brown. Preorbital region of the head transparent. Throat whitish. Belly black. Muscular part of tail reddish, with black markings. Fins grey. Anal tube dextral.

MEASUREMENTS

	mm.		mm
Total length	32·00	Breadth of Body	. 8·00
Length of head and body	10 00	Depth of body	5 00
Length of tail .	22·00	Depth of tail .	.. 6·50

Locality.—Streams of Kempholey, Hassan.

Philautus nassutus

The tadpoles are not large. The head and body rather elongated and narrowly oval. Both surfaces are convex. The snout is rounded, slopes downwards. Dorso-median line grooved in some cases. Mouth small, shorter than the interorbital space which equals the internasal width. Eyes and nostrils dorso-lateral. Latter nearer to the eyes than the tip of the snout. Spiracle tubular, lateral pointing backwards. Spiracular opening nearer to eyes than the root of the hind limbs. The mouth disc is small Both lips well developed Upper fringed with papillæ Sides lobate, borders with more than one row of papillæ Lower lip provided with three lobes, covered with numerous papillæ Upper beak broadly V-shaped with a serrated border No teeth The tail is long and powerfully developed The dorsal and ventral fins attain maximum depth in the posterior half of the tail The muscular portion broader The dorsal fin does not extend beyond the root of tail Tail pointed Anal tube dextral Skin smooth Upper surface bright yellow, with dark irregularly distributed dots. The muscular part of tail yellow with clusters of black spots, sometimes running together to form bands Under surface of body white Caudal fins grey

MEASUREMENTS

	mm		mm.
Total length . .	32 00	Greatest width of body	11 00
Length of head and body	12 00	Greatest depth of body	9 00
Length of Tail	21 00	Greatest depth of tail	8 00

Locality —Streams of Kempholey, Hassan

Philautus pulcher

The tadpoles are comparatively small Head and body narrowly oval, moderately flattened above and below In a few cases the upper surface is convex The snout is rounded, sloping downwards Diameter of the mouth about ¾ in the interorbital width, which is broader than the interorbital space Eyes dorso-lateral Nostrils point upwards, nearer to the eyes than to the tip of snout Spiracle distinctly tubular, directed upwards Spiracular orifice nearer to the eye than to the root of the hind limb. The mouth disc is small Upper lip not developed, but bears a lobe provided with a double row of papillate border Sides lobate, lower lip multilobed, both bearing minute papillæ The upper beak broadly crescentic with a smooth border, lower serrated Tail strongly developed Upper fin commences well behind the root of the tail, both fins are well developed and are of the same depth The upper broadly arched, the lower being nearly straight Tip of tail pointed Skin smooth Upper surface of head and body slate coloured Undersurface grey Muscular part of tail yellow, with black markings, running into longitudinal or vertical streaks Latter marking prominent in the hinder half of the tail Anal tube median

MEASUREMENTS.

	mm.		mm.
Total length	27 00	Width of body . .	5 00
Length of head and body	9 00	Depth of body .	4 00
Length of tail	. 18 00	Depth of tail . .	4 00

Locality —Streams of Kempholey, Hassan

Philautus variabilis

The tadpoles are of moderately large size, the head and body being oval Dorsal surface slightly flat, ventral distinctly convex The snout is rounded, sloping down Mouth ventral Nostrils nearer to the tip of the snout, internasal space almost equal to interorbital width, eyes dorso-lateral, nostrils point upwards. Eyes nearer to the tip of the snout than to the spiracular opening The spiracle is lateral, sinistral, orifice directed upwards and backwards Mouth disc small, surrounded by broad lobes fringed with rows of papillæ The upper lip has two rows of papillæ The lower lip is divided into four lobes, the hinder border bearing small papillæ The upper beak is broadly U-shaped and the lower V-shaped, having a serrated margin Dentral rows absent The tail is well developed The upper lobe does not extend beyond the roof of the tail The upper fin is deeper than the lower, but less deep than the muscular part Tip of tail pointed Skin smooth, dorsal surface yellowish, with numerous dark dots The muscular part of tail yellow with dark irregular blotches Sometimes the inferior border of the lower fin, may bear fine black dots, confined to the posterior division No preorbital and frontal glands No sensory pits

MEASUREMENTS

	mm		mm.
Total length .	40 00	Breadth of body	. 8 00
Length of head and body	13 00	Depth of body	. 6 50
Length of tail	. 27 00	Depth of tail	5 00

Locality —Streams of Kempholev, Hassan

Rana aurantiaca

These tadpoles by their uniform brown colour are apt to be mistaken for those of *Bufo*, and it is interesting that the larvæ of *Rana aurantiaca* the adult of which is beautifully coloured, are so drab The size of these tadpoles, their oral and caudal characters, distinguish them at once from the larvæ of *Bufo*

The tadpoles are of moderate size Head and body oval, not flattend dorso-ventrally, both surfaces being convex Snout rounded, mouth small, ventral Eyes dorsal or dorso-lateral Nostrils pointing laterally Width of mouth equals or less than the interorbital width which is broader than the internarial spaces Nostrils equidistant between tip of snout and eyes Spiracle lateral, sinistral, somewhat broadly tubular, pointing slightly upwards The mouth disc is small, lower lip better developed The upper free from papillæ which occur on the sides and on the outer borders of the lower lip, with a distinct median space free from papillæ The upper beak is broadly crescentic with a smooth border, the lower is broadly V-shaped, finely serrated Dental formula $\frac{1}{3}$ The tail is broad The dorsal fin extends beyond the root of the tail Both fins are almost equal, but slightly deeper than the muscular portion Pointed at the tip Anal tube slightly dextral Both surfaces of the body and the muscular portion of the tail uniformly brown Tail fins lightly coloured

MEASUREMENTS

	mm		mm
Total length	. 31 00	Greatest width of body	5 75
Length of head and body	12 00	Greatest depth of body	5 75
Length of tail	19 00	Greatest depth of tail	7 50

The tadpoles live near the water margins on the tanks at the base of hills and occur in small numbers Mostly they rest on the floor

Locality —Base of Anamalai Hills, Coimbatore District

Bufo brevirostris

Generally speaking, the tadpoles of the genus *Bufo* are comparatively small and those of *B brevirostris* are extremely so These were taken from rain water puddles from which the adults were obtained Besides these tadpoles those of *B* ***melanostictus*** and *B* ***microtympanum*** also were collected from the same situation It is interesting to note that the shoals of tadpoles belonging to the different species keep together separately and it is this distinctive feature of their habits that led to their examination Like the other members of the genus, the body is obcordate the greater width being at the pectoral region The snout slopes and is rounded The diameter of the mouth equals or is greater than the interorbital space The eyes and nostrils are distinctly dorsal, looking upwards Interorbital width (1·5 mm) is greater than the internasal space (1·0 mm), the nostrils nearer to the eyes than to the tip of the snout Upper lip devoid of papillæ which fringe the sides and the outer borders of the lower lip Both lips are equally developed Dental formula 1 $\frac{1}{3}$ The second series in the upper lip is interrupted in the middle, the three lower series are continuous almost equal to one another The jaws are finely serrated Skin smooth A pair of preorbital glands present Sensory pits on the back absent A frontal gland is prominent Spiracular tube opens slightly dorsalward situated about the middle of the body, not visible from below Length of tail about 3½ times its total length Both fins are poorly developed, the dorsal being slightly arched.

Tips of tail pointed The colour of the dorsal surface is brownish Undersurface uniformly whitish Fins of tail grey

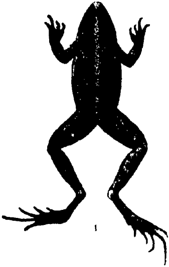
MEASUREMENTS

	mm		mm
Total length	13 00	Maximum breadth of body	3 75
Length of head and body	6 00	Maximum depth of body	2 75
Length of tail	7 00	Maximum depth of tail	2·00

The tadpoles of this species of *Bufo* can be easily recognised from the other described forms by the oral papillæ and serrated jaws

EXPLANATION OF FIGURES

FIG 1. *Rana parambikulamana*, actual size.
FIG 1a Side view of head × 2
FIG 1b Undersurface of hand × 2
FIG 2 *Rana lucorhyncus* × 2
FIG 2a Side view of head × 2
FIG. 3 *Rana intermedius* × 1½
FIG 3a. Side view of head × 1½.
FIG 4 *Rana sauriceps* × 2
FIG 4a Side view of head × 2
FIG 4b Undersurface of hand × 3
FIG. 4c. Foot × 3
FIG 5 *Rana tenuilingua* × 3
FIG 5a. Side view of head × 3
FIG. 6 *Nyctibatrachus sylvaticus* × 1½
FIG 6a Side view of head × 1½.
FIG 7 *Nannobatrachus kempholeyensis* × 3
FIG 7a Side view of head × 3
FIG 8 *Bufo brevirostris* × 2
FIG 8a Side view of head × 2
FIG 9 *Philautus charius* × 2
FIG 9a. Side view of head
FIG 10 *Philautus elegans* × 3.
FIG. 11 *Philautus kottigeharensis* × 2
FIG 11a Side view of head × 3.
FIG 12. *Philautus swamianus* × 2.
FIG 12a. Side view of head × 4.
FIG. 13 *Philautus melanensis* × 2
FIG 13a Side view of head × 2
FIG 14 *Philautus narainensis* × 2.
FIG. 14a. Side view of head × 3.



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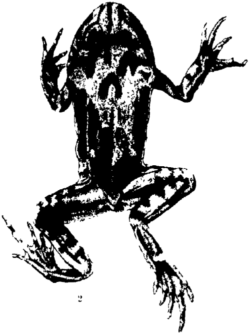

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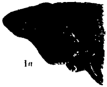

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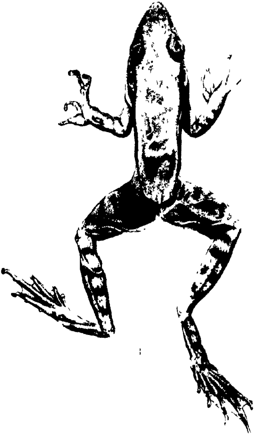
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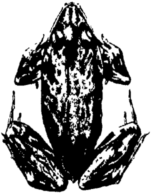
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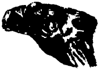
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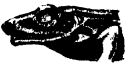
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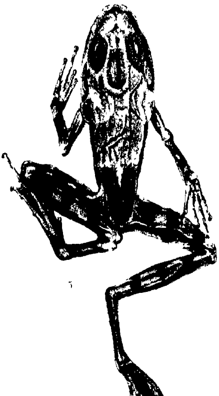

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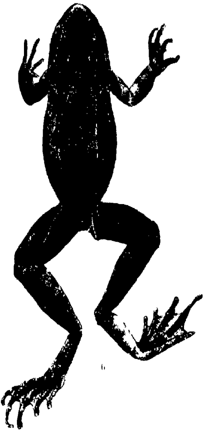

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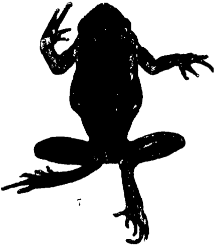

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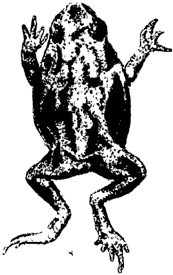

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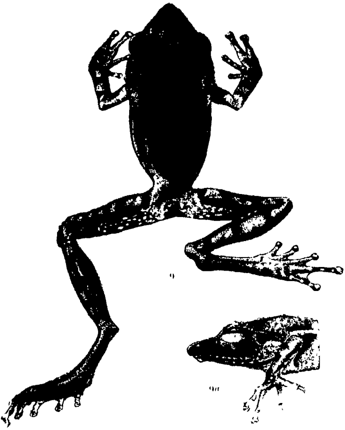

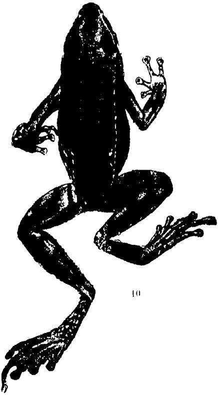

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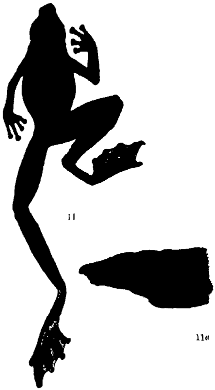

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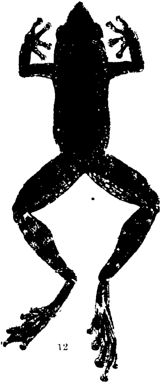

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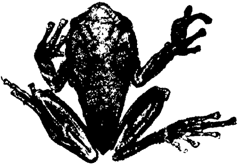

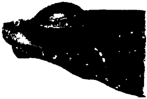

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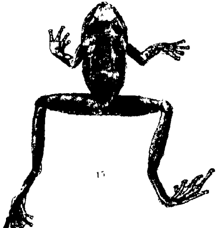

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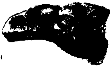

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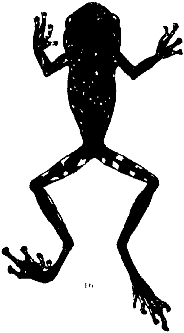

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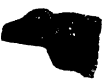

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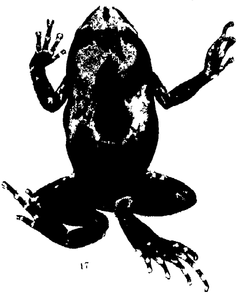

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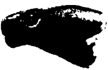

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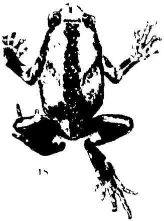

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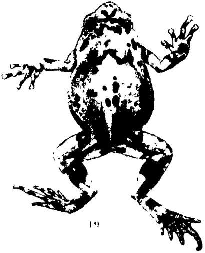

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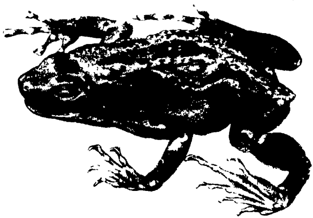

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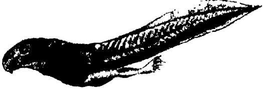

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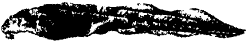

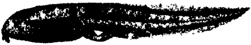

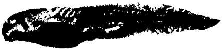

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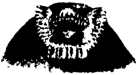

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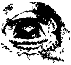

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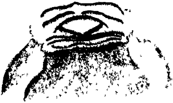


27a

Fig. 15 ***Philautus longicrus*** × 2
Fig 15*a* Side view of head × 3.
Fig. 16 ***Philautus montanus*** × 1½
Fig 16*a*. Side view of head × 2
Fig 17 ***Ramanella minor*** × 3
Fig 17*a* Side view of head × 3
Fig 18. *Ramanella triangularis rufiventris* × 2
Fig. 18*a* Side view of head × 3
Fig. 19 *Ramanella mormorata* × 2
Fig. 19*a* Side view of head × 3
Fig. 20. *Ramanella anamalaiensis* × 3

TADPOLES

Fig 21 ***Philautus leucorhynchus*** × 3
Fig 21*a* Mouth disc × 5
Fig 22 ***Philautus hypomelas*** × 3
Fig 22*a* Mouth disc × 10
Fig 23 ***Philautus nassutus*** × 3
Fig 23*a*. Mouth disc × 10
Fig 24 ***Philautus pulcher*** × 3
Fig 24*a* Mouth disc × 5
Fig 25. ***Philautus variabilis*** × 2
Fig. 25*a* Mouth disc × 10
Fig 26 ***Rana aurantiaca*** × 3
Fig 26*a* Mouth disc × 10
Fig 27 ***Bufo brevirostris*** × 5
Fig 27*a* Mouth disc × 15

ON THE OCCURRENCE OF WINGED SPORES IN THE LOWER GONDWANA ROCKS OF INDIA AND AUSTRALIA.

By Miss Chinna-Virkki, B A , M Sc
(Research Fellow, Department of Botany, Lucknow University)

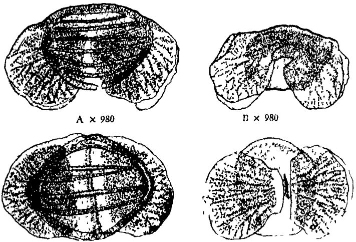
Received December 27, 1937
(Communicated by Prof B Sahni, F R S)

During an investigation of fossil cuticles from some carbonaceous shales in the Lower Gondwana rocks of the Salt-Range, Punjab, numerous spores were discovered, some winged, others unwinged Some of the two-winged spores showed a striking resemblance to Professor Seward's *Pityosporites antarcticus* which was suspected by him to be a pollen-grain of *Glossopteris* [1, 2] Two of these spores are shown in Fig 3 *A*, *B* The wings in both the spores are reticulately marked and are of the same size measuring about 37 μ The striped body in each slightly differs in size—*A* measures about 4 μ and *B* about 40 μ

The geological section from which these and other spores were obtained is a typical Lower Gondwana section with the Talchir Boulder bed at its base, and it includes more than one horizon containing *Glossopteris*, *Gangamopteris*, and other forms The first spores were found in some specimens presented to Professor B Sahni by Mr E R Gee of the Geological Survey of India Subsequently similar specimens were collected by myself at the same locality [3]

After this a piece of shale from the Permo-Carboniferous rocks of Newcastle, New South Wales, was examined for cuticles as well as spores This shale is so rich in the fronds of *Glossopteris Browniana* Brong that rarely a bare face of the rock is exposed Though I did not succeed in obtaining good samples of cuticles, numerous two-winged pollen-grains, all showing a general resemblance with *Pityosporites antarcticus* were found, some in groups, but chiefly lying free A few spores were even seen adhering to small pieces of cuticle (see Fig 1 *C*, *D*) No clear evidence of sporangia is available Some of these Australian spores are shown in Figs 1 and 2 lying in different postures, mostly dorsal, but rarely lateral, ventral and polar

There are two sizes of spores represented in these figures The smaller size (Fig 1 *A*-*C*, Fig 2 *A*-*D*) possesses reticulately marked wings, about 27 μ across, which in some spores appear to be united on the dorso-lateral



A × 980   B × 980

C × 980   D × 980

Fig 2

Camera-lucida drawings of *Pityosporites Sewardi* sp. nov Permo-Carboniferous of Newcastle, N S W, Australia From a piece of shale crowded with *Glossopteris Browniana* Brong

A. *Pityosporites Sewardi* sp nov Lateral view of the spore in Fig 1, *I* × 980

B *P Sewardi* sp nov The union of the two wings on the dorso-lateral side of spore, in Fig 1, *B* × 980

C *P Sewardi* sp nov. Dorsal view Striped body seen above and the wings below × 980

D *P Sewardi* sp nov Ventral view showing the two wings × 980

side (Fig 1 *B*, Fig 2 *B*) The body, with a relatively thick wall, measures about 36 μ in diameter, and shows a number of well-marked horizontal stripes (Fig 1 *A*, Fig 2 *A*, *C*) On the other hand, the wings and the body of the larger spores (Fig 1 *D–F*) measures about 30 μ and 50 μ respectively In their striped body and reticulate wings these larger, lighter coloured spores show almost identical structure with the smaller ones Even in living plants it is not uncommon to find different sizes of spores within the same sporangium That the difference in preservation may also be responsible for this difference in size seems not impossible However, after a careful examination of a large number of these spores I am inclined to refer them provisionally to two separate species

The parentage of none of these spores, Indian or Australian, can be determined with certainty The circumstantial evidence, however, strongly favours the view that they both represent the pollen-grains of *Glossopteris*

The Newcastle spores were obtained from the surface of the cuticle of *Glossopteris Browniana* Brong., from a shale which consists solely of fronds of this species; maceration of the rock matrix did not yield spores. The spores were obtained in hundreds from a small bit of this shale. As stated above they show a striking resemblance with *Pityosporites antarcticus*. As already stated, spores of a similar though not identical kind occur in the Permo-Carboniferous rocks of the Salt-Range, again in association with *Glossopteris*. Lastly, from Professor Seward's paper[2] it appears that Hamshaw Thomas has found evidence of winged spores of *Glossopteris* in South Africa. If his spores too resemble the others it can be said that winged spores of the general *Pityosporites* type occur in the *Glossopteris*-bearing rocks in widely scattered parts of Gondwanaland, namely, Antarctica, South Africa, India and Australia.

It must, however, be mentioned that the possibility of these spores being other than those of *Glossopteris* cannot be overlooked. No organic continuity is seen between the frond and these spores. Nor is there any clear evidence of the sporangia which must have contained them. Unless more light is thrown in this direction it cannot be said with any certainty that these are the pollen-grains of *Glossopteris*. But on the evidence available at present one is inclined to believe that these winged pollen-grains most probably belong to *Glossopteris* and that Professor Seward's unfortunate *Pityosporites antarcticus*, which met with adverse criticism, is after all a pollen-grain and most probably of *Glossopteris*. I have pleasure in naming the Australian spores of the smaller size shown in Fig. 1 *A–C*, Fig. 2 *A–D*, after the discoverer of the antarctic pollen-grain, as *Pityosporites Sewardi* sp. nov.

A detailed description of all these spores and others, both winged and unwinged, found in the Lower Gondwana rocks of the Salt-Range, will appear in a subsequent paper.

I wish to express my grateful thanks to Professor B. Sahni, F.R.S., for his ready help, invalauble criticism and never failing encouragement.

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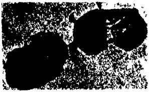
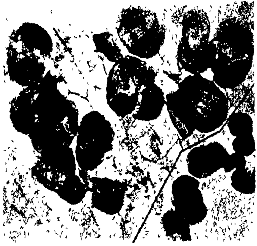
A ×400

B ×400

E ×400


F ×400


D ×340 C ×340

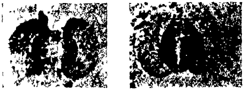

A ×380 B ×380

FIG 3

EXPLANATION OF PLATE

Fig 1 Untouched photographs of *Pityosporites Sewardi* sp nov and *Pityosporites* sp. (larger spores) Permo-Carboniferous of Newcastle, N S W, Australia From a piece of shale crowded with *Glossopteris Browniana* Brong

- A *Pityosporites Sewardi* sp nov Lateral view with the two wings attached to the striped body × 400 See also Fig *2 A*
- B *P Sewardi* sp nov The union of the two wings on the dorso lateral side × 400 The same spore is drawn in Fig *2 B*
- C *P Sewardi* sp nov Adhering to a piece of cuticle of *G Browniana* Brong × 340
- D *Pityosporites* sp Adhering to the same piece of cuticle as *C*, mostly showing their dorsal aspect × 340
- E *Pityosporites* sp The one on the right side shows the two wings attached to the striped body × 400
- F *Pityosporites* sp Ventral view. × 400

Fig 3, A, B Ventral view of the two-winged spores with striped body and reticulate wings From a horizon 1½ ft above the Talchir Boulder Bed Loc Kathwai, Salt-Range, Punjab × 380 (Coll C Virkki)

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